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NATURAL HISTORY

JANUARY 1976

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NATURAL HISTORY

Incorporating Nature Magazine
Vol. LXXXV, No. 1
January 1976

The American Museum of Natural History
Robert G. Goelet, President
Thomas D. Nicholson, Director

Cover: *The bald eagle has become a ruffled national symbol as the effects of pesticide poisoning, indiscriminate shooting, and habitat destruction have severely depleted its range and numbers. Photograph by Tom McHugh, Photo Researchers, Inc. Story on page 8.*

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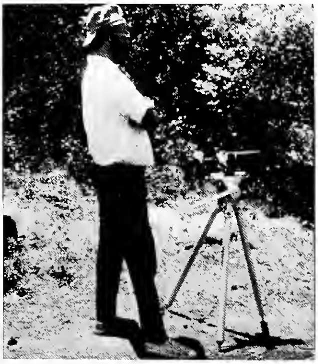
Authors

With the approach of the Bicentennial, *Natural History* decided to publish an uncommon portrait of an American symbol: the bald eagle. **David R. Zimmerman,** a free-lance writer who has often reported on birds of uncertain future, was sent to the government's Patuxent Wildlife Research Center where autopsies are performed on bald eagles. His findings paint a grim prognosis for the national bird. Zimmerman, whose book, *To Save a Bird in Peril,* was published last year, authored "Vulture Restaurant" for the June–July 1975 issue of *Natural History.*



Alexander Duncan first encountered Nepalese metal casters in 1970, on what was supposed to be a brief trip to India and Nepal, which has not yet ended. For a while he worked at Tribhuvan University in Kathmandu, but at the moment he is doing independent research in the field of Nepalese bronzes and casting with attention also to Tibetan art in general. Duncan plans to write a book on the subject of Nepalese bronzes, both traditional and modern. Free-lance photographer **James Kittle's** interest in image casting was fostered by his friend Alexander Duncan.

For six years **Douglas Osborne** directed archeological excavations in Colorado's Mesa Verde National Park. A principal objective of the project was to determine why the Pueblo Indians abandoned the area some 700 years ago, a mystery that first intrigued Osborne during his student days at the University of New Mexico. Now teaching anthropology at California State University, Osborne—who has participated in at least a dozen digs in the western United States and Canada—is at present investigating archeological sites on the South Pacific island of Palau, an area in which he has long been interested.

Concerned about the future welfare of the black bear in the southern Appalachian Mountains, **Michael R. Pelton** began to explore the natural history and ecology of this animal. One by-product of his inquiry was the development of accurate census-taking methods for the species. Supervisor of a graduate research program at the University of Tennessee, where he is an associate professor of forestry, Pelton was able to enlist the services of several students in the black bear study. Now engaged in field work on the exotic European wild hog and the raccoon, Pelton plans to increase the scope of his examination to include the gray fox, skunk, and bobcat. Coauthor of

"Black Bears of the Smokies," **Gordon M. Burghardt** focused on the problems created by human–black bear interactions in the Great Smoky Mountains National Park. An assistant professor of psychology at the University of Tennessee, Burghardt is studying the behavior of newborn snakes and newly hatched green iguanas in Panama and is also planning to write a book on ethology. Financial support for the project on the black bear was provided by McIntire-Stennis funds obtained through the Department of Forestry, a National Institutes of Health grant, and the Great Smoky Mountains Natural History Association.

Announcing . . . The 1976 Natural History Photography Competition

For those who received new cameras for Christmas, for those who are restless to get outdoors with their old ones, and for all whose files are brimming over with beautiful pictures, *Natural History* joyfully announces another chance to try your luck: the photo contest is on again.

This year we have included black-and-white photography, kept the theme broad, and opened separate categories for those with specialized techniques. We have altered the rules a bit, juggled the judges, and changed the prizes. So read on.

The Categories: 1. The Natural World, including Man. 2. Macro- and Microphotographs, including scanning electron micrographs. 3. A Chronological Sequence, which may be up to five photographs, of an "Event in Nature."

The Rules: The competition is open to everyone except employees of The American Museum of Natural History and their kin and all previous winners. 2. Competitors may submit up to three previously unpublished entries in each category. 3. Entries may be transparencies or prints up to 8" by 10". Each entry must contain the name and address of the photographer and the category. 4. For each entry, please tell us the camera model used. 5. Include a self-addressed, stamped envelope since we want to return your pictures to you.

The Closing Date: All entries should be postmarked no later than April 1, 1976.

The Rewards: Grand Prize is $500. First prize for each category is $250. Ten Honorable Mentions will receive $100 each.

More Rewards: All winning entries will be published in a special, picture-filled issue of *Natural History.*

Some Hitches: The decision of the judges will be final. *Natural History* acquires the right to publish and exhibit the winning pictures. And *Natural History* assumes no responsibility for transparencies or prints.

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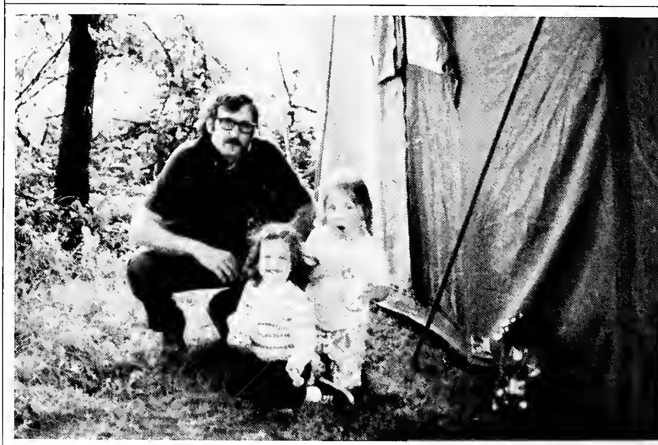
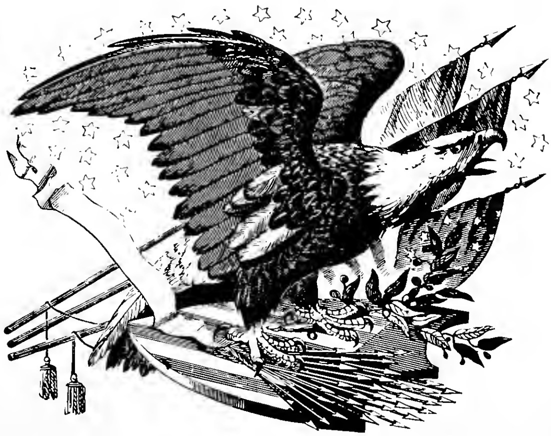
The bones being held by anthropologist **Adrienne Zihlman** are half a human pelvis (in her left hand) and half a chimpanzee pelvis (in her right hand). During ten years of work on pelvises, Zihlman has dissected dozens of primate hip joints and studied countless pelvic and limb bones in South and East Africa. Interested in the development of human locomotion and its correlation with social behavior, she is currently completing a book on the evolution of human society. Since finishing her graduate studies in 1967, Zihlman has taught anthropology at the Santa Cruz campus of the University of California. Coauthor **Douglas Cramer,** who teaches anthropology at Rutgers University, has also worked as a medical and surgical illustrator. He is responsible for many of the illustrations in the article.



Perplexed by the long-standing medical controversy over the role of fever in disease, **Matthew J. Kluger** became involved in the problem three years ago when he was appointed assistant professor of physiology at the University of Michigan Medical School. In the belief that animal models would yield some answers about the adaptive value, as well as the origin and evolution, of fever, he has been working with lizards, birds, and small mammals. (One incidental laboratory finding was that opossums do not get sick.) Kluger, who received his Ph.D. from the University of Illinois in 1970, spent two years at the Yale University School of Medicine investigating temperature physiology.

The Bald Eagle Bicentennial Blues



by David R. Zimmerman

America's national bird is falling under the weight of poison and gunshot

Long enmeshed in allegory, the bald eagle is acquiring a doleful, new role as a symbol of Americans' destruction of their natural heritage.

As before, the great bird is shot, beaten, and driven from its range, even as it is celebrated as the expression of our national courage and resolve. Its new encumbrance is more subtle, but it may signify wider, more all-pervasive danger.

Bald eagles are among our most polluted birds. They carry larger amounts of a wider variety of chemical contaminants than virtually any other American species.

This distressing news comes from an ongoing study of bald eagles found dead or dying in the wild. The federal government asks that a state wildlife agent or a special agent of the U.S. Fish and Wildlife Service (USFWS) be notified when a dead bald eagle is discovered. It is the agent's job to retrieve, freeze, and ship the carcass to the USFWS's Patuxent Wildlife Research Center, near Laurel, Maryland, on the outskirts of Washington, D.C. The agent also is asked to provide any "history" that might indicate the cause of the eagle's demise.

At Patuxent, a research group performs gross autopsies and chemical analyses on the eagles. The autopsies are conducted by veterinarian-histopathologist Dr. Louis N. Locke. Chemical residues are measured by analytical chemist William L. Reichel, who directs Patuxent's sophisticated pesticide-monitoring laboratory. Excepting those birds that arrive too rotten for study, the Patuxent group has analyzed the remains of some 300 bald eagles in the last decade. Of this number, almost half died of gunshot wounds.

Case 982, for example, was a healthy female eagle found dead in Albany Township, Stearns County, Minnesota, in November of 1974. Locke's autopsy report says: "Death had been caused by a rifle bullet which had entered the thorax through the upper left pectoral muscles, penetrated the [breastbone], passed through the upper thorax and exited just posterior and lateral to the left [shoulder bone]."

The special agent who sent the eagle provided little data on the circumstances of its death, but Locke found a strong, if unverifiable clue: the remains of a white leghorn chicken in the eagle's mouth and stomach.

The eagle's dark, immature head

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feathers and the small size of its ovary and the egg follicles within it told Locke that this bird had never bred. Although his official report does not say so, this is more the shame, since 982 was one of the "cleanest" eagles, in terms of chemical residues, of any sent to Patuxent.

Through the years, Reichel has sharpened and refined his analytical techniques, including gas chromatography and mass spectrometry, to the point that he routinely seeks, and finds, a dozen different chemicals in the eagle brain and body tissues that he analyzes. He found absolutely none in the brain of 982. In the body he found only insignificant amounts of the DDT breakdown product DDE (0.14 parts per million) and of the chemically related industrial compounds called polychlorinated biphenyls, or PCBs (0.3 ppm). Had she not had the misfortune to run into a bullet, eagle 982 almost certainly could have bred normally—and so contributed to her species' survival.

Whether the subject on the autopsy table is a human cadaver or a bird carcass, the pathologist's success depends in part on his skill as a detective and in part on serendipity. In case 986, for example, Locke's initial diagnosis was "electrocution."

The special agent who submitted the eagle, Charles Q. Heumier, works out of the Brigham, Utah, USFWS office. He said the remains had been found "near a well-traveled roadway, about 20 yards from a 2-wire powerline on crossarms.

"The bird was frozen [when found], and appeared to have been dead for quite some time. The carcass may have been moved some by dogs. A farmhouse is nearby."

Agent Heumier added: "I was unable to find any bullet holes. Usual evidence of electrocution was not noted."

Locke, however, was able to find the presumptive evidence of electrocution that agent Heumier had missed: singed feathers high under the left wing and along the adjacent chest wall. He also found a bloody, dime-sized laceration leading past the last left rib into the lungs.

"Because of the singed feathers and the history—found near powerline—the significance of the laceration . . . was not appreciated at the time of autopsy," Locke wrote later. His initial diagnosis: "Electrocution, with laceration following the fall to the ground."

Completing his autopsy, Locke followed a standard procedure and removed the eagle's brain, kidneys, and liver for chemical assay. He removed the skin, feet, wings, and gastrointestinal tract. The feathers he put aside; when a boxful accumulated they would be sent to a USFWS special agent in the West, who gives them to Indian artisans to fashion into ceremonial headdresses.

The flesh and bones of eagle 986, the better part of its original 11.5 pounds, were then put through a food-grinding machine so that a small but representative specimen of the carcass, one-third of an ounce, could be taken for organochlorine analysis. Grinding an eagle is a routine task, but eagle 986 provided a surprise—"a .22-caliber rifle slug was found in the ground meat."

Locke thereupon abandoned his original diagnosis. "The better interpretation is [that] the eagle [first] was shot, then fell against the powerline and received the singed feathers. In all probability, the bullet slug was lodged in the blood-filled lungs."

While rarer than shooting, electrocution deaths do occur. A marine biologist in Florida wrote to explain how eagle 1011 met its end.

"On March 31, 1975, at about 6:30 P.M., my neighbors . . . observed a small bald eagle pick up the filleted carcass of a 36-inch kingfish, which had been thrown over the seawall.

"The eagle carried the fish across two wires of a high tension powerline and was electrocuted."

The loss is the greater because this eagle, a male, is believed to have been one of a breeding pair that was busy raising eaglets in a nearby eyrie.

Bald eagles that breed in Florida, and as far north as the 40th parallel—which runs through Philadelphia and Denver—are assigned to the southern subspecies *Haliaeetus leucocephalus leucocephalus,* which has been reduced to a few hundred breeding pairs and is considered highly endangered. The marginally larger northern subspecies, *H. l. alascanus,* all bald eagles that breed north of the 40th parallel, is far less threatened; the USFWS estimates there are 35,000 to 50,000 in Alaska alone.

One of the northern subspecies, eagle 857, was found frozen and dead in a fox trap near Kodiak City, Alaska, and was forwarded by Kodiak Wildlife Refuge manager Gerry Atwell, who knew enough of the circumstances to blame "an inexperienced trapper" for the bird's demise.

Pathologist Locke verified "trap injuries" on the feet, but attributed death to a skull fracture. "A hard blow . . . had been delivered. . . . Skull fragments had been driven inward by the force of the blow and ruptured the large vessels of the meninges. Posterior portion of the right cerebral hemisphere reduced to pulp."

The eagle's desperate last seconds are easily visualized, but Locke passes no judgment on the humans involved. "I don't think there are many people who are going to walk up to an angry eagle and try to get him out of a trap. They either shoot him or beat him over the head with a club."

Eagles suffer other kinds of human-induced trauma. One eagle was struck by a car. Two flew into airplane motors. The most surprising case, according to Locke, involved an eagle that was seen perched on a snag over water, trying to free itself from a large fishhook caught in one nostril. The eagle reached up with one leg to kick off the hook, caught the leg on the hook, lost its balance, fell into the water—and drowned.

More insidiously, about 5 percent of the eagles sent to Patuxent died of acute poisoning by strychnine and thallium, which are predator control compounds. The great majority of the eagles autopsied at the research center thus had died from unnatural, often violent, humanly induced causes. This begs the question whether all bald eagles die of a like distribution of causes; probably not, but the answer is that nobody knows.

The dead eagles received at Patuxent are a biased sample of the bald eagle population. Like human autopsy series from medical examiners' offices, a major source of Locke's cases are lawmen—USFWS special agents. The series thus is weighted toward those deaths that lawmen learn of and follow up on.

They may be most interested in deaths where there is a suspected human perpetrator since bald eagles are protected by law, and killing one can invite a federal indictment. So, as in suspicious human deaths, the cases of violence may be a disproportionate part of the sample. On the other hand, an eagle carcass is easier to hide than a human corpse, and there is no way to know how many eagles shot in sport or in vengeance then are buried

where the law will not discover them.

The Patuxent series is also geographically biased. From 1964 to 1972, only 5 of 190 eagles came from Alaska, although that state has more than 90 percent of this country's bald eagles. Only 2 birds came from California, another important bald eagle state, while there were 6 from Florida and 29 (representing 15 percent of the total) from Wisconsin.

Where an eagle died, however, may say little about the importance of its death for the subspecies populations. Unless it actually has been seen breeding or caring for young, there is no way to know whether an eagle that died in Florida came from the relatively threatened southern population or from the far larger—and less impacted—population of northern breeders, many of which wander south in winter.

Many eagles move north and south seasonally, but no one knows if they follow regular migratory pathways. One reason is that few eagles carry leg bands; it takes a bander with a stout heart and strong back, plus a sheaf of permits, to climb eyries to band bald eagles. And in the past the effort was of dubious value. "You couldn't band bald eagles," Reichel explains. "They chewed the bands off. That had the biologist stumped!" In the spring of 1975, however, new-type bands, which will stay on eagles, were issued and will be standard.

Few strong correlations have been found between the states of the union where the birds were found and their chemical loads. One is that dead eagles in Alaska tend to be cleaner than many of the others, although "dirty" birds are found there too. "You can have high and low values for eagles from the same state," Reichel says. "But where these eagles have been before, we don't know."

One dramatically clear correlation involves death due to lethal levels of the insecticide dieldrin. Because this chemical and the other organochlorine compounds that Reichel routinely looks for are nerve poisons, lethal levels are based on residues in the brain, not the carcass. Feeding studies with other species of birds and analyses of animals found dead in dieldrin-treated fields have convinced the Patuxent researchers that levels of 4 ppm of dieldrin in the brain are likely to be lethal. Nineteen out of 190 eagles, or 10 percent of those found dead up to 1972, had more than 4 ppm of dieldrin in their brains.

"The incidence of dieldrin poisoning is high, particularly among the specimens collected from Maryland, Virginia, South Carolina and Florida," Reichel and his colleagues recently reported. "Of the 17 eagles collected [from the southeastern seaboard], 8, or 47 percent, possibly died from dieldrin poisoning. . . . All four from Maryland and Virginia were from the Chesapeake Bay tidewater area."

Not surprisingly, breeding bald eagles have practically vanished from the Chesapeake Bay area, although dieldrin certainly is not the only factor. Also, while autopsy data are sparse, studies in the field show that bald eagle colonies near other large, tidal bodies of water, which seem to act as pesticide "sinks," have been severely threatened in recent years. Those that are far from large bodies of water have done much better.

The bald eagle's problems are aggravated because it feeds at the top of a pesticide-concentrating food chain; fish are a principal part of its diet. This has led the director of the Patuxent Center, population ecologist Dr. Lucille Stickel, to say that "Bald eagles haven't got much going for them! They choose to live in the most polluted areas in the United States. And they choose the most polluted food source."

Lethal brain loads of DDT and its metabolites and lethal levels of PCB have been found in very few eagles.

Difficulty arises in interpreting those cases in which the brain loads are just shy of known deadly levels. This difficulty is compounded when high, but sublethal, levels of two or more pollutants are present. Stickel says there is some evidence to suggest that several poisons together may lower the lethal threshold of one of them. Tests in which two or more poisons are fed to birds (not eagles) in sublethal doses are in progress at Patuxent. When combined lethal levels for DDT, dieldrin, and PCB are established, some eagles whose final diagnoses remain open may be put into the poisoned category.

Even less well understood are the effects of sublethal doses on an eagle's over-all health and ability to survive. Might half the known lethal amount of dieldrin, for example, so compromise a bird's health that stress, which it otherwise would survive, proves fatal?

Eagle 853 illustrates this problem. She was a very emaciated, immature

female bird found in a pasture in Wildwood, Florida, in a weakened condition. She seemed alert, but refused food, had difficulty breathing, and soon died. Locke tentatively attributed death to intestinal parasites—nematodes and flukes—found in her gastrointestinal tract. In her brain, chemist Reichel found dieldrin at one-third the lethal level (1.5 ppm), DDE at one-tenth the lethal level (26 ppm), and PCB at about one-fifth the lethal level (43 ppm). Also, while Reichel excludes residues outside the brain in assessing lethality, he found strikingly high levels of DDE (110 ppm), DDD (7 ppm), dieldrin (4 ppm), and PCB (180 ppm) in the body. The eagle also carried comparatively high levels of mirex, the fire ant poison, in the brain (1.8 ppm) and body (8.3 ppm)—the significance of which is uncertain.

"The case of parasites may have made the lethal levels lower," Reichel says. "Or, look at it the other way around: Maybe these levels [in the brain] lowered its resistance and made it more subject to the parasites. I don't think we have enough to hang our hat on. But this [case] illustrates the problem."

Chemical death may be suspected long before the eagle's flesh is extracted for a trip through the gas chromatograph. A bird seen trembling and shaking convulsively is one for which Locke's index of suspicion is high.

At autopsy, there are other signs. Birds killed by pesticides tend to be very thin. Their bodies are devoid of fat, even around the coronary arteries, the most stable fatty area outside the brain. Ingested organochlorines are deposited in fat. When a bird is under stress—because it has been acutely poisoned by pesticide and is too sick to eat or is migrating or is using body resources to build eggs—body fat is mobilized into the bloodstream along with its chemical residues. The fat is burned for energy, and the pesticide tends to be reabsorbed by fat in the brain, which, unlike body fat, remains essentially stable, even in severe stress.

The organochlorine residues in body fat thus are a sword, poised to fall on a bird just when it most needs its energy reserves to meet a stressful challenge. No one knows what level of residue in the body will produce a lethal level in the brain when the bird is stressed.

Chemicals kill some bald eagles outright, but this is not their only contribution to the species' decline. Organochlorines also disrupt the female reproductive system, and as a result the breeding success of bald eagles in contaminated regions such as the coast of Maine is low.

The key question is, At what levels of these residues is reproduction impaired?

Reichel says, "That's a hard one! I don't think that anybody has enough data yet to suggest that a certain amount in the carcass will produce a certain level in the eggs, and that this will have an effect on reproduction."

Stickel concurs. "I cannot say—and I don't think anyone can say—how many of the eagles we have autopsied had, or would have had, reproductive problems. It's safe to say that some did."

Pressed to say why she and her colleagues will not be more specific, Stickel says too many conjectures are required at this point to say that a certain body burden of poisons will produce reproductive failure. "There is a relationship. We could make predictions. But it is too long a chain scientifically, and we have not chosen to make that jump."

A colleague, Dr. David Peakall, who works in the Canadian Wildlife Service laboratory in Ottawa that is Canada's equivalent to the Patuxent laboratory, agrees that the data are sparse. But he is willing to hazard an estimate, based largely on field data from peregrine falcons. The bald eagle, he says, seems to be at least as sensitive as the peregrine to reproductive loss due to DDE.

Peakall estimates that the DDE levels in eggs are 15 to 40 percent of the levels that will be found in the brains of female birds who lay them. Peregrines, he says, begin to experience reproductive difficulty at the equivalent of 1.5 to 4 ppm DDE in the brain. The average of Patuxent's median brain levels of DDE in bald eagle brains for four recent years is 2.4 ppm. This suggests that had they lived at least half the female eagles would have been subject to some degree of reproductive handicap.

The damage caused by organochlorines to bald eagles and other birds cannot yet be totaled. But since the use of these chemicals has been curtailed, it is fair to ask whether—and when—residue levels will decline and bird populations recover.

The use of DDT began to drop in the United States more than a decade ago, and a virtually complete ban was put into effect in 1972. Dieldrin was banned in 1974. The sole United States manufacturer of PCB has voluntarily restricted its sale. But continuing discoveries of large amounts of PCB being discharged into the environment by manufacturers of electrical equipment and other industrial users have convinced scientists that further limits are needed—quickly.

Mirex may again be used against the fire ant in the southern states despite the program's recent cutback. And the federal Environmental Protection Agency (EPA) is considering restrictions on chlordane, an agricultural chemical that is also used on lawns and for termite control.

According to the EPA, these restrictions have begun to reduce organochlorine residues in humans and in wildlife. One study found that the level of DDT in songbirds fell from 17 ppm to 4 ppm—a very significant reduction—in the decade from 1964 to 1973.

For reasons that are not clear the Patuxent data does not offer comparably reassuring news for the bald eagle. The median levels of DDT group residues and dieldrin were virtually the same, if not higher, in 1973/74 as they were in 1964/65. The PCB levels were roughly the same in 1973/74 as they were in 1971, the first year for which they were reported.

Bald eagles live longer and so may absorb greater amounts of chemicals than other birds. Unlike short-lived songbirds, older bald eagles may carry residues picked up years ago. The eagles may be particularly vulnerable because they take their prey from chemical sinks, such as tidal waters. Then, too, there is a hint in the data, Stickel says, that bald eagles may be less able than other birds to metabolize and excrete dieldrin.

Whatever the reason(s), for the bald eagle there seems to be no surcease, as yet, from environmental poisons. "As far as the data I have compared go," Reichel says, "I have not seen any drastic change. That stuff will be around for quite a while!"

Americans today seek ways to reanimate the national spirit for which the bald eagle was chosen as a symbol in 1782. One appropriate challenge would be to act, with alacrity, to restore the environmental health of our natural heritage—so that our national bird can survive. ☐


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In America — for perhaps the first time — flags were anners of the *People* themselves. Symbols of *their* hopes, spirations, and ideals. With Independence those flags ecame the emblems of Independent Sovereign States, eriving their powers from the consent of the people hemselves. The perfect embodiment of independent spirit, aditions, determination, and sense of destiny which the eclaration of Independence proclaimed.

History remembers that Virginia's Flag, which shows Virtue ith her foot on Tyranny, was inspired in 1776 by George Mason's suggestion that his State's motto should be a defiant *Sic semper tyrranis* (thus always to tyrants). And that New Jersey's buff flag recalls the color chosen in 1779 by George Washington for the uniforms of New Jersey's regiments fighting for Independence.

Now, two centuries later, the thirteen flags have grown to fifty. Each flag the proud emblem of the people, the heritage, the unique strengths, and the rich diversity of the fifty States of the Union. Each intimately woven from the fabric of America's proud history.

An unprecedented philatelic event

It is more than fitting, therefore, that as a part of the Nation's Bicentennial Celebration, the United States Postal Service will issue on February 23, 1976, an unprecedented series of *fifty* different Official Commemorative stamps portraying *The Flags of the Fifty States*. This will be the *first* such series to honor *all* fifty state flags, and like all firsts, certain to command the special attention of collectors and historians everywhere.

Crafted expressly for this series, each of the fifty different *cachets* will pay tribute to the State's most distinguished citizen today honored in the National Statuary Hall of the United States Capitol.

Our National Capital's Post Office will *officially* postmark each First Day Cover. Available only at Washington, the coveted *First Day of Issue* indicia will forever certify the one day and the one place the first edition of the new stamp was inaugurated.

Each of the fifty Official commemorative stamps will be issued by the United States Postal Service pursuant to law. Since stamps will be issued *only* on February 23, 1976, artists' concepts are used herein for illustrative purposes only.

SHOWN SMALLER THAN ACTUAL SIZE OF 3⅝ BY 6½ INCHES.

Available to you: the First Editions

The assembled Governors of all fifty States and other leading citizens will gather in the Nation's Capital on February 23 to inaugurate the new stamps. At special ceremonies, *first editions* of the new stamps . . . First Day Covers . . . will be officially certified by the coveted, one-day-only, *First Day of Issue* postmark of our National Capital's Post Office. These Official First Day Covers will be but a *small fraction* of the total number of stamps eventually printed and available to the general public.

Appropriately, America's oldest and largest purveyor of First Day Covers has for months been making painstaking preparations for the First Day of Issue of *The Flags of the Fifty States*. World-renowned for its First Day Covers, Fleetwood will issue *The Flags of the Fifty States* in *one complete* collection of fifty individual Official First Day Covers. The first fifty collections have been reserved for the Archives of each of the fifty States. Identical collections are also available now to private citizens on an advance reservation basis.

A remarkable collection

This is the very first collection of First Day Covers *ever* dedicated exclusively to all fifty States of the Union. As befits such a series, each will be extraordinary in every respect.

The individual *cachets* will portray one great citizen from each State who, under an Act of Congress, has been honored in the National Statuary Hall of the United States Capitol in Washington. These are men and women "illustrious for their historic renown or for distinguished civic or military services" to their State and Nation. They are the proud sons and daughters who have given substance to the vision of our Declaration of Independence.

Among them: *William E. Borah*, "The Lone Lion of Idaho." *Samuel Adams*, firebrand and Signer of the Declaration of Independence from Massachusetts. *Thomas Starr King*, whose matchless oratory saved California to the Union. And, *John C. Calhoun* of South Carolina, the pre-eminent champion of the Union, the South, and States' Rights.

A deluxe collector's album will be included

Collectors who take advantage of this opportunity to acquire the Official First Day Covers of *The Flags of the Fifty States* will also receive, without additional cost, a handsomely bound collector's album, with protective dustcase. To enhance the historical and educational value of this collection, an authoritative reference guide will be provided with biographies of the citizens honored on the *cachets*. And the fascinating history of each state Flag.

WORLD GLOBE © RAND McNALLY

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A single, genuinely limited edition

The Flags of the Fifty States will be issued *only once* — on the precise First Day of Issue, and *only* as a complete collection. The distinctive postmark will certify to you that *The Flags of the Fifty States* can *never* be issued again.

The original issue price for the complete collection of fifty Official First Day Covers is $70, and you may pay for it in its entirety now, charge it to your MasterCharge or BankAmericard Charge account, or pay for it on a convenient installment program.

A collection of timeless significance

The Official First Day Covers of *The Flags of the Fifty States* deserve an honored place in your home. As constant reminders of the great and unique contributions which each of the States have made to the Nation born two hundred years ago this July 4th. And as a legacy which will continue to inspire you, your children, and their children for generations to come.

Subscription deadline: February 15

Please remember that this is the *only time* that the Official First Day Covers of *The Flags of the Fifty States* can ever be issued. To take advantage of your opportunity to acquire this collection, postmark order no later than February 15, 1976 — the last date on which Fleetwood can guarantee acceptance of your order. Applications should be sent directly to Fleetwood, Cheyenne, Wyoming 82008.

ADVANCE SUBSCRIPTION APPLICATION
THE OFFICIAL FIRST DAY COVERS OF

The Flags of the Fifty States

To be postmarked
not later than February 15, 1976

Fleetwood GA
Cheyenne, Wyoming 82008

Please accept my subscription for the Official First Day Cover Collection of *The Flags of the Fifty States*. The collection will consist of 50 impeccably cacheted Official First Day Covers to be sent to me under protective cover following the Official First Day of Issue date, February 23, 1976. Shipment at intervals beginning approximately six weeks thereafter and concluding approximately twelve weeks after the issue date. The original issue price is $70 for the complete collection, which I prefer to pay as follows:

☐ I enclose $10 in partial payment of the total price of $70. I am to be billed for the balance in four monthly installments of $15. There is no finance charge.
☐ I enclose my remittance of $70 as payment in full.
☐ I prefer to have the full amount of $70 charged to my credit card account listed below:
☐ MasterCharge ☐ BankAmericard

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FLEETWOOD WILL ACKNOWLEDGE YOUR SUBSCRIPTION.
Established 1929, Fleetwood, a division of Unicover Corporation, is America's oldest and largest purveyor of First Day Covers. It is not affiliated with any governmental agency.

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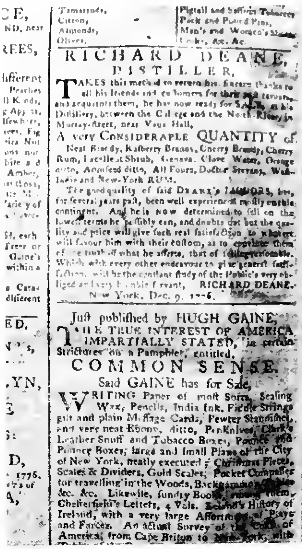
by Richard M. Klein

A Nation of Moonshiners

Americans have produced and imbibed alcoholic beverages from colonial days on down



Tamarinds, Citron, Almonds, Olives.

Pigtail and Saffron Tobacco, Pock and Pound Pins, Men's and Women's [illegible] Locks, &c. &c.

RICHARD DEANE, DISTILLER,

TAKES this method to return his sincere thanks to all his friends and customers for their past favours, and acquaints them, he has now ready for Sale, at his Distillery, between the College and the North-River, in Murray-street, near Vaux Hall,

A very CONSIDERABLE QUANTITY of

Neat Brandy, Rasberry Brandy, Cherry Brandy, Cherry Rum, Excellent Shrub, Geneva, Clove Water, Orange ditto, Anniseed ditto, All Fours, Doctor Stevens, West-India and New-York RUM.

The good quality of said DEANE's LIQUORS, has, for several years past, been well experienced [illegible] continent. And he is NOW determined to sell on the lowest terms he possibly can, and doubts not but the quality and price will give such real satisfaction to whoever will favour him with their custom, as to convince them of the truth of what he asserts, that of [illegible]. Which with every other endeavour to give general satisfaction, will be the constant study of the Public's very obliged and very Humble Servant, RICHARD DEANE.

New York, Dec. 9, 1776.

Just published by HUGH GAINE,

THE TRUE INTEREST OF AMERICA IMPARTIALLY STATED, in certain Strictures on a Pamphlet, entitled,

COMMON SENSE.

Said GAINE has for Sale,

WRITING Paper of most Sorts, Sealing Wax, Pencils, India Ink, Fiddle Strings, gilt and plain Message Cards, Pewter Standishes, and very neat Ebony, ditto, Penknives, Clark's Leather Snuff and Tobacco Boxes, Pounce and Pounce Boxes; large and small Plans of the City of New York, neatly executed; Christmas Pieces, Scales & Dividers, Gold Scales, Pocket Compasses for travelling in the Woods, Backgammon [illegible] &c. &c. Likewise, sundry Books, [illegible] Chesterfield's Letters, 4 Vols. [illegible] History of Ireland, with a very large Assortment of Plays and Farces. An actual Survey of the Coast of America, from Cape Briton to New-York, with

New York Historical Society

Ad in 1776 newspaper for various spirituous liquors.

Cognizant of its awesome responsibilities in guiding our nation, the Eighty-eighth Congress of the United States of America on May 4, 1964, passed joint resolution 19, introduced by Senator Thruston Morton and Congressman John C. Watts, honorable gentlemen of the great state of Kentucky, which contained the following proviso:

> That it is the sense of Congress that the recognition of Bourbon whiskey as a distinctive product of the United States be brought to the attention of the appropriate agencies of the United States Government towards the end that such agencies will take appropriate action to prohibit the importation into the United States of whiskey designated as Bourbon. . . .

As might be expected, resolution 19 was far from the first congressional act to deal with distilled beverages. Certainly one of the earliest was a law enacted by the first general assembly of Virginia in 1619:

> Against drunkenness be it also decreed that if any private person be found culpable thereof, for the first time he is to be reprooved privately by ye Minister, for the second time publically, the thirde time to lye in boltes 12 howers in the house of ye Provost Marshall and to paye his fee.

These two quotations demonstrate the sinfulness and profitability of distilled spirits in the United States: twin themes that run throughout our entire experience with liquor.

Although production and consumption of low-proof alcohol predate recorded history, Aristotle mentioned that one could obtain the spirit of wine. Greek and Egyptian alchemists in the second century A.D. obtained rectified, or distilled, liquids and, in the process, apparently stumbled upon ardent—as opposed to mild—spirits. Yet, distilling entered the thinking of Europe only when the Crusaders learned the technique from North Africans. A treatise on distilling appeared in France in 1310, and by 1500, there were learned books and practical manuals on the preparation of brandy from wine, aqua vitae from beer, and the fabrication of medicinal cordials from herbs infused in grain alcohol made from wheat, barley, and millet. Our English word *whiskey* is derived from the Gaelic *uisgebeatha*, or water of life (aqua vitae). Originally, the drink was a medicine, an all-purpose cure containing anise, cloves, nutmeg, ginger, caraway, licorice, sugar, and saffron, in addition to alcohol.

The preparation of alcohol is simple. Basically, any carbohydrate source is fermented with yeast and the 8 to 13 percent alcoholic solution is refined by distilling the alcohol out of the water. In Europe and its colonies, the medieval alembic, a closed vessel to which heat was applied, was charged with the ferment and the alcoholic vapors were passed through a pipe in the vessel's top to a twisted metal "worm" immersed in cold water to condense the vaporized alcohol. In addition to alcohol, the distillate contained a wide variety of volatile compounds that gave specific odors and flavors to the brew.

When grain is the source of carbohydrate, fermentation is initiated either by adding sugar, which can be fermented by the yeast, or supplying the enzyme amylase, which converts starch into sugar. Amylase, present in sprouting grain, is formed in response to the secretion from one tissue into another of gibberellic acid, a substance that regulates plant growth. Barley is an excellent source of amylase. The grain is wetted, allowed to sprout, dried with gentle heat, and the seedlings are then ground into malt.

Scotch whisky's distinctive taste comes in part from the practice of

Maker's Mark Distillery

One-hundred-year-old steam engine for yeast room.

drying the malt over peat fires. Grain is ground into meal, boiled into a gruel to make its starch soluble, malt is added, the gruel is inoculated with yeast and allowed to ferment to produce a beer that is then distilled. Most yeasts stop working when the alcohol content reaches a maximum of 12 percent, at which point the alcohol can be distilled away from the beer. The resulting mash can be refermented several times, and the spent mash used as animal feed. (Colonists derived much innocent amusement from seeing how drunk their pigs would get on spent mash.)

For reasons lost in the idiocies of history, the early settlers failed to bring the alembic and worm with them when they crossed the Atlantic and their drinking was thus restricted to beer, ale, and wine. But with Yankee ingenuity, just about all the colonists' produce could be used as a base for beer. Pumpkins, potatoes, sea plums, Indian corn, carrots, and even turnips were made into beer. Northern New Englanders used honey from wild bee trees and the sap of the maple pointed out to them by friendly Indians.

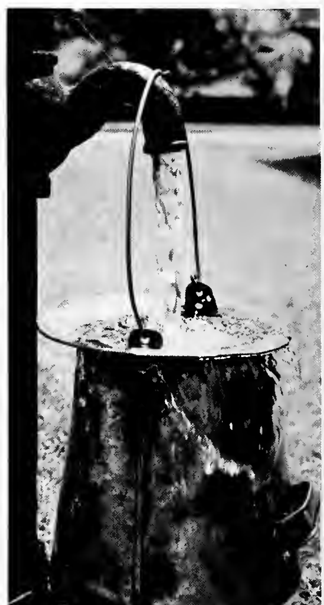
Along with other necessities, the colonists carried seedling fruit trees from Europe and orchards were planted as soon as the land was cleared. Hard syder, about 4 to 5 percent alcohol, was made from crabb trees, and the first blooming of apples, peaches, and pears was greeted with cries of rejoicing. The alcoholic content of these syders was increased to about 25 percent by putting the jugs outside in winter and getting rid of the water content by carefully removing the ice. Peaches were especially favored in the Virginia colonies because they fermented into a somewhat stronger product than apples and plums, with a delightful odor and taste. Elderberries, currants, and the wild but foxy-tasting grapes were used for wine. Ardent spirits—the whiskeys—were not routinely used. Brandy was a standard medicinal of ship's stores, and rum made from molasses on the sugar plantations of the West Indies had to be transshipped to the colonies via England.

Distilling apparatus was, of course, soon put into use. At first, a blanket was placed over a kettle and the condensed vapors were simply wrung out into a pail. But each village had a mechanically inclined inhabitant who constructed an alembic and worm from bits and scraps of wood and metal, and by 1630, applejack and crude grape, peach, and pear brandies were being made. The fruit brandy of New Jersey was considered the most potent, capable of producing an "apple palsy" after just two drinks.

Capt. John Smith planted maize in Jamestown, Virginia, in 1607 and a year later the colony made corn beer from it. Those experiments on malting maize were duly noted and barley was planted elsewhere as soon as possible. Wilhelm Keift, director-general of the Dutch colony on Staten Island, distilled grain in 1640 with imported barley malt mixed with imported rye and native maize. Brandy was produced from imported grapes by 1650 and aged from two to four years in barrels fashioned from native white oak instead of the oak species of France. Gin, too, was made in America by 1660, but never attained the popularity it achieved in England. In contrast to the European varieties, American gin was not made entirely of wheat and barley malt, but utilized corn—creating a strange taste—and the botanicals included the berries of native junipers, which were also different from those of Europe. A mixture of gin and applejack, called "strip and go naked" because it induced this behavior after several mugfuls, was imbibed by the poor in northern cities. It was tamed for servants and women by adding beer and blackstrap molasses.

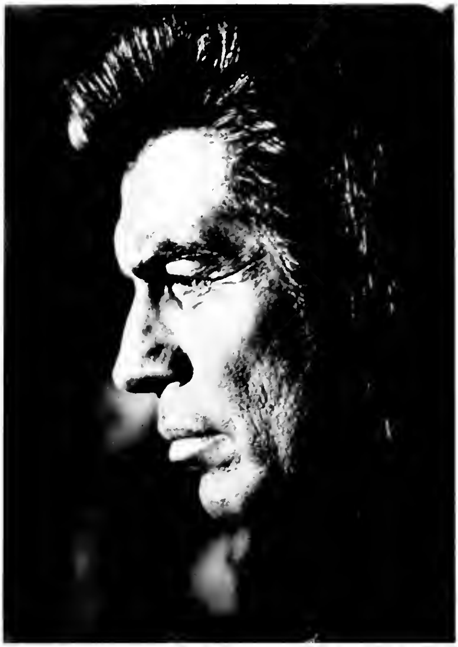
The Puritans of the Massachusetts colonies favored rum, usually served on social occasions as a rum flip. A mixture of rum, beer, and sugar was stirred with a logger—a heated iron poker; after a half dozen potions, the guests were frequently at loggerheads. Rum is a distillate of either yeast-fermented sugarcane syrup or the molasses left after the crystallization of the sugar. Blackstrap molasses, a dark brown, caramellike end product, is the most common starting material. The rum initially consumed in the colonies was made in the West Indies, but by 1660 the Salem, Newport, and Medford branches of the Massachusetts colonies were importing molasses to make their own dark, high-proof product. Benjamin Franklin, first president of the American Philosophical Society, devised a walloping drink for membership dinners (and his lady friends) consisting of high-proof Medford or Demarara rum, loaf sugar, and orange juice.

Most of the sugar refineries were in French or Spanish hands, but Britain, preferring to keep the lucrative mo-



Maker's Mark Distillery

Limestone water—a crucial ingredient of bourbon whiskey.



Maker's Mark Distillery

Old copper equipment used in the distilling process.

lasses trade entirely English, attempted through the molasses act of 1733 to limit the profits of the hated foreigners by requiring that Medford rum be shipped to England or, if kept for local consumption, be taxed at home-country rates. The molasses act had two effects. It increased rum smuggling and was as distasteful to the colonists as the stamp, navigation, and tea taxes. As a substitute for rum, New Englanders fermented and distilled the honey from native bee trees. Called "old metheglin," the beverage was a dark brown, sweet drink of about 60 percent alcohol content. In Vermont it was traditionally assumed that one glass was enough—even in winter—to cause the buzzing of the bees to be heard.

Wheat and barley grew poorly in the colonies; in addition, the wheat was needed for bread and most of the barley was needed for making beer malt. Rye, not a native plant, accordingly formed the base for the first whiskeys made in the colonies. It flourished in western Maryland and eastern Pennsylvania, lands settled by Germans from Moravia and by Scotch-Irish Presbyterians descended from Scots who had previously lived in Ulster. These settlers had both the skills and equipment to make whiskey and they set to it with a will and fervor that was part of their heritage. Rye whiskey was originally called "tiger spot," but it soon became known as either Maryland or Monongahela.

There were good economic reasons for the industry of the distillers. A packhorse could carry no more than four bushels of grain, but the same horse could, and did, carry two kegs of whiskey representing twenty-four bushels of rye. Spoilage was minimal, unless the horse or driver stumbled, and the two kegs brought the equivalent of forty bushels of grain. The fermentation and distillation of rye and barley malt produced a whiskey with a heavy, intense flavor, in great contrast to the rye that the contemporary, unenlightened drinker mixes with ginger ale. We have been sold a bill of goods: Today's rye is little more than a smallish amount of whiskey mixed with pure alcohol, water, and caramel coloring.

Despite its success in Maryland and Pennsylvania, rye was not a good crop in the South or on the western frontier. The weather was too warm and there was often excessive rain in midsummer. The settlers, therefore, turned to a cereal grain that did grow well—the maize of the Indians. As Virginians moved west, they established villages that were sufficiently remote to require their own legal structures. By 1770, Harrodsburg, Harwood's Landing, and Boonsfort, all in Kentucky, were recognized agricultural communities that grew corn for food, fodder, and fermentation. By 1780, Fayette, Jefferson, and Lincoln Counties were legally established in the western Virginia lands, a judicial District of Kentucky (then spelled Kentuckey) was formed in 1783, and Bourbon County was cut out from Fayette in 1786.

The population of Kentucky in the late eighteenth century was more than "thirty thousand souls," of which a goodly proportion were growing corn. Who first started making corn likker in Kentucky is unknown, but there are several claimants for this exalted title. Among them: Marsham Brashears, who purchased land in 1782 for 165 gallons of whiskey; Jacob Froman, who was indicted twice (in 1784 and 1785) for retailing liquor without a license; and Bartlett Searcy, who willed his 96-gallon still to his son John in 1784. For the sake of convenience, the Reverend Elijah

Craig, a Baptist minister, is usually credited with making the first bourbon whiskey in about 1780. He lived in Georgetown, Scott County; not Bourbon County, but close to it. Elijah's brother Lewis, also a Baptist minister, was a whiskey dealer who supplied the cargo for the flatboats that followed the rivers down to New Orleans.

There was serious debate in those days as to the propriety of ministers engaging in the liquor trade, but since most parishioners were similarly employed, no pot could call any kettle black. Consumption before services or during revival meetings, however, was dealt with severely. And drunkenness occasionally led to outright expulsion from the congregation: a man—and his wife—were supposed to be able to handle their liquor. The Baptist argument raged on until about the time of the Civil War when a firm antiliquor stand was taken.

As the rye from Maryland and Pennsylvania and the corn whiskey from Bourbon County became widely distributed, the role of liquor in social, business, and political affairs became so all-pervasive in the region as to constitute the ordinary way of life. Full or partial payment for debts, mortgages, and purchases of necessities was made in liquor. Gallons of whiskey and distilling apparatus were formally considered parts of estates; births, weddings, and funerals were paid for and celebrated in whiskey; and business arrangements were consummated with pledges sloshed down with a cupful or a glassful. Morning dawned with an eye-opener consisting of whiskey in which bitter herbs had been steeped; camomile flowers were a common additive. Prophylactic doses of whiskey warded off the often fatal effects of getting soaked in a thunderstorm. A sovereign remedy for "summer complaint" of both children and adults was an infusion of rhubarb, caraway seed, and orange peel in whiskey, and copperhead or rattler bites were treated internally and externally with bourbon.

Most distillers were the Kentucky farmers themselves, who took advantage of the fine, pure limestone water available and the abundant corn. None of the products were trademarked; they were all bourbon or rye. By 1760, a James Beam and a J. W. Dant had moved to Kentucky from North Carolina and a John Ritchie and a Jacob Beam were licensed distillers from 1770 to 1780, but it was not until after the revolutionary war that specific names were attached to the product of a distillery or a district. Elijah Ripper of Lexington, Kentucky, was making corn whiskey by 1770 and his grandson James E. Pepper sold "Old 1776" during the nineteenth century, a trademark that unfortunately died out in World War II. Prior to, and even after, the Revolution, whiskey was collected at Louisville or Cincinnati and barged down the Ohio and Mississippi rivers to be distributed in the southwest and southeast via New Orleans. John James Audubon subsidized his then

Guy Gillette, Photo Researchers

Fermenting vats in contemporary distillery.

ignored paintings when, as a merchant in Henderson, Kentucky, he shipped kegs of bourbon whiskey to Missouri where he sold the liquor at two dollars a gallon.

The whiskey of the colonists was sold and consumed in its God-given, natural, water-clear state. Occasionally a small amount of caramel coloring was added to give the liquid the amber hue associated with European brandy. The colonists knew that aging in charred oak barrels imparted a golden brown color and smoothed out the product through the marriage of various esters and organic compounds, but the practice took valuable time and no one cared a whit what the color was as long as the drink was strong. Besides, the long trip by horse and barge in the hot sun provided all the aging that was necessary. The complex of harsh, skull-popping volatiles (evil-smelling fusel oils, aldehydes, and wood alcohol) could be absorbed by barrel aging or simply by filtering the raw whiskey through a layer of maple charcoal. Peach brandy was similarly treated with charred peach pits, which also contained a minute amount of prussic acid. One serious problem was the tendency of the alembic to overheat and scorch the mash, but some genius figured out a way to introduce live steam into the pot still to volatilize the alcohol. Only much later, when distilling had become big business, did the continuous Coffey still method replace the one-shot pot.

By the beginning of the eighteenth century, copper stills imported from England or Holland were in general use. Most native stills were fashioned from iron, which imparted an off flavor and sometimes colored the water-clear liquid. British restrictions on local manufacturing made rolled copper for alembic, worm, and steam boiler impossible to obtain. Paul Revere, a silversmith—and sometime horseman—was best known for being the only manufacturer of rolled copper in the colonies, a monopoly that he held until 1802.

Proof, or strength, was determined by the gunpowder method. Equal volumes of gunpowder and whiskey were mixed and set afire. If the preparation flashed up, the whiskey was too strong; if it didn't burn, it was too weak. When it burned evenly, the whiskey was 100 percent perfect; it was proved out and the proof was 100. (Since pure alcohol is 200 proof, 100 proof indicates an alcohol content of 50 percent.)

Although rye whiskey was made by inoculating mash with fresh yeast, much of the bourbon utilized the sour-mash process in which the mash, before fermentation, was charged with a small amount of liquid from the previous batch. This so-called spent beer contained a small amount of lactic and other acids, which promoted the development of yeasts and repressed the growth of bacteria that might otherwise spoil the taste of the whiskey. The same principle is used in making pickles and sauerkraut.

The colonists were more particular about the taste than the spelling of their liquor and the *y* or *ey* endings

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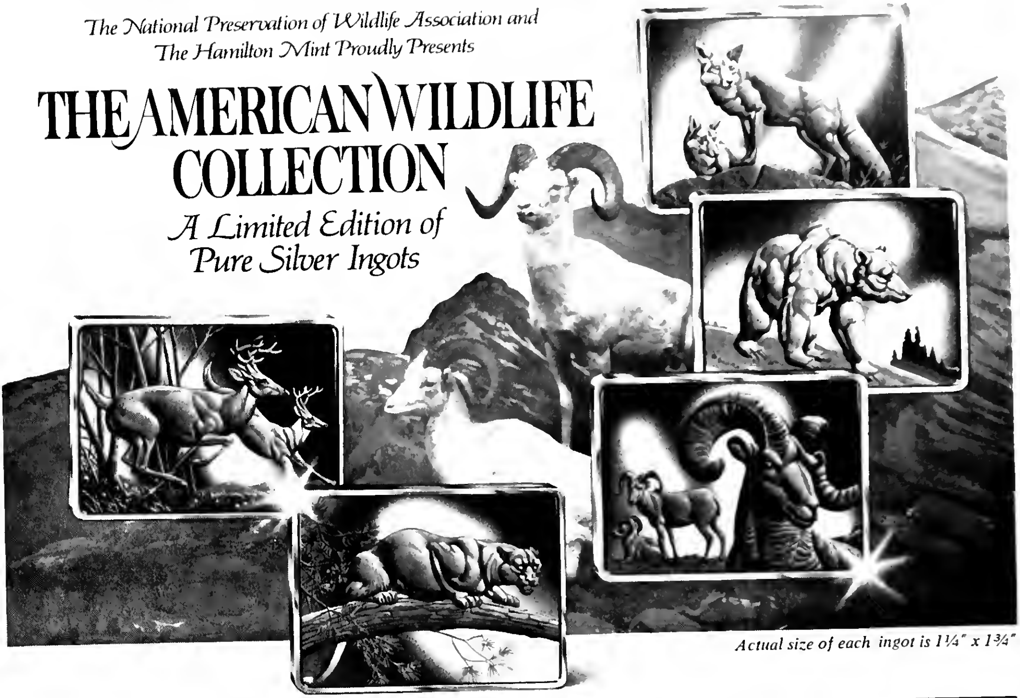

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"The American Wildlife Collection" Series of 50 ingots is one of the most comprehensive collections ever issued by The Hamilton Mint. It combines superb visual beauty with lifelike portrayals of each animal.

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Your "American Wildlife" ingots will be custom minted to your order and will bear your own personal serial number plus The Hamilton Mint Hallmark. Serial numbers will be assigned in the order that applications are received, with the lower and more desirable numbers going to the earliest subscribers. You will also receive a Certificate of Authenticity, certifying the limited edition status and precious metal content of the series.

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The edition will be strictly limited to just 10,000 proof sets in silver, issued at the rate of two-a-month for a period of 25 months. Once this edition limit has been reached, the minting dies will be destroyed, thus safeguarding the integrity of the edition.

The original issue price for each ingot will be just $14.95, and this price will be guaranteed to subscribers over the entire issue period no matter how the price of silver may rise. And, a portion of the proceeds of each sale will go to the National Preservation of Wildlife Association, a non-profit organization dedicated to protecting our wildlife.

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Subscribers will receive a handsome display case, free of charge, to house the entire Collection. Also *at no cost*, you'll receive *a special bonus*, "Nature Atlas of America," a beautiful 255 page volume with 361 full color photographs and illustrations. This handsome book is a large 8½" x 11" and has a deluxe library binding.

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Guy Gillette, Photo Researchers

Bottling the final product for distribution.

were used interchangeably until about 1850. Frances Trollope used both spellings in her 1832 book, *Domestic Manners of the Americans.* After the Civil War the *ey* ending was restricted to the rye, Canadian, and bourbon whiskeys of the Western Hemisphere.

George Washington learned the value of whiskey very early. In 1758 he stood for the Virginia House of Burgesses from Frederick County and won with a total of 307 votes—at a cost of £38, £34 of which was spent on liquor. At the time, rum was 16 shillings per gallon, rye whiskey was 8 shillings per gallon, corn liquor was 4 shillings per gallon, and there were 20 shillings to the pound. The money was well spent. By contrast, James Madison, who refused to supply refreshments for the voters, consistently lost elections. Washington's plantation was noted for its peach brandy, and as his liquor became ever more famous, he branched out into making a whiskey from rye and corn and imported a Scotsman to oversee the business. However, he had competition from others, including the Byrd, Mason, Madison, and Jefferson families.

During the revolutionary war, Washington insisted that the army be supplied a liquor ration: "In many instances such as when they are marching in hot and cold weather . . . it is essential that it [liquor] not be dispensed with." He recommended to the Continental Congress that public distilleries be erected to supply liquor to the troops. The young American navy, following the British model, also had its daily tot of rum. With many men away from their farms during the war, grain was in short supply. Washington noted with approval the restrictions imposed by the colonies on excessive use of grain for whiskey making and insisted that the liquor ration consist of peach or apple brandy or of rum. This did not sit too well with the southern and western troops weaned on corn and rye likker, but their complaints were dampened by the high-proof rum passed out by supply sergeants. Wartime profiteering became evident as the price of rum rose fourfold in a year. The ration of spirits given to sailors was ended by an act of the Thirty-seventh Congress in 1830 and the adjutant general of the army supinely went along in 1862.

Governments have always taxed liquor, and citizens have always attempted to evade payment. The young Republic, in a desperate search for a means to pay the debts resulting from the Revolution and to cover the growing obligations of statehood, considered the imposition of a whiskey excise. Alexander Hamilton, the secretary of the treasury, and his Federalist party rammed through Congress the Excise Tax Act of 1791, which empowered the federal government to impose duties on all spirits "distilled within the United States, from any article of the growth and produce of the United States, in any city, town or village." Progressive duties on each gallon according to its proof and a yearly tax on each still were mandated, together with an onerous responsibility laid on each producer to maintain records and permit the inspection of distilleries, ware-

houses, taverns, and even private homes. Indignation ran high. Kaintucks, Virginians, Tennesseans, and Pennsylvania rye distillers were hailed into court for back excises; the Reverend Elijah Craig had a liability of $140 assessed against him and nearly went bankrupt, as did many others. This excise, they all agreed, was an invasion of rights won with their blood. They had fought the British for freedom from excisemen and they would be damned if they were going to go through that again. Although the excise was softened in 1792 and again in 1794, distillers joined with shippers and retailers to oppose the tax, and meetings and resolutions gave way to direct opposition, which included tarring and feathering the tax collectors, shooting up the homes of the excisemen, and an occasional murder. The violence was meant to be a test of the power of the federal government to tax the people directly, without the interposition of the states, and Hamilton convinced Washington that the whiskey rebels of the Monongahela Valley must be permanently crushed.

With a penchant for military overkill that seems to mark our country's defense establishment, a massive army was gathered. By the autumn of 1794, 13,000 troops armed with artillery, mortars, and other appurtenances of a punitive force—and supplied with whiskey—had been mustered. General Henry (Light-Horse Harry) Lee, then governor of Virginia, smelled powder and volunteered to lead one section of the troops through the Cumberland Gap near the point where Virginia, Kentucky, and Tennessee meet. General Howell and the New Jersey contingent moved through Carlisle, Pennsylvania, and Washington himself made an appearance on a white horse to show that the government really knew what it was doing. Happily, there was no battle; the rebels wisely dispersed. At a cost of about $1.5 million, the excises were collected. Jefferson, who never supported any of Hamilton's ideas, repealed the whiskey tax when he assumed the presidency in 1801 and it was not reimposed until the Civil War. For better or worse, depending on your point of view, it has never been removed since.

Richard M. Klein, who is not a teetotaler, teaches botany at the University of Vermont.

Darwin and the Captain

If Darwin wasn't the ship's naturalist, what was he doing on the Beagle*? And why did Captain Fitzroy shoot himself?*

Groucho Marx always delighted audiences with such outrageously obvious questions as "Who's buried in Grant's tomb?" But the apparently obvious can often be deceptive. If I remember correctly, the answer to who framed the Monroe Doctrine? is John Quincy Adams. Most biologists would answer "Charles Darwin" when asked, "Who was the naturalist aboard the H.M.S. *Beagle*?" And they would all be wrong. Let me not sound too shocking at the outset. Darwin was on the *Beagle* and he did devote his attention to natural history. But he was brought on board for another purpose, and the ship's surgeon, Robert McKormick, originally held the official position of naturalist. Herein lies a tale; not just a nit-picking footnote to academic history, but a discovery of some significance. Anthropologist J. W. Gruber reported the evidence in "Who Was the *Beagle*'s Naturalist?" written in 1969 for the *British Journal for the History of Science*. Last year, science historian H. L. Burstyn attempted to answer the obvious corollary: If Darwin wasn't the *Beagle*'s naturalist, why was he on board?

No document specifically identifies McKormick as an official naturalist, but the circumstantial evidence is overwhelming. The British navy, at the time, had a well-established tradition of surgeon-naturalists, and McKormick had deliberately educated himself for such a role. He was an adequate, if not brilliant, naturalist and performed his tasks with distinction on other voyages, including Ross's Antarctic expedition (1839–1843) to locate the position of the South Magnetic Pole. Moreover, Gruber has found a letter from the Edinburgh naturalist Robert Jameson addressed to "My dear Sir" and full of advice to the *Beagle* naturalist on collection and preservation of specimens. In the traditional view, no one but Darwin himself could have been the recipient. Fortunately, the name of the addressee is on the original folio. It was written to McKormick.

Darwin, to cut the suspense, sailed on the *Beagle* as companion to Captain Fitzroy. But why would a British captain want to take as a companion on a five-year journey a man he had only met the previous month? Two features of naval voyages during the 1830s must have set Fitzroy's decision. First of all, voyages lasted for many years, with long stretches between ports and very limited contact by mail with friends and family at home. Secondly (and however strange it may seem to our psychologically more enlightened century), British naval tradition dictated that a captain have absolutely no social contact with anyone down the chain of command. He dined alone at every meal and met with his officers only to discuss ship's business and to converse in the most formal and "correct" manner.

Now Fitzroy, when he set sail with Darwin, was 26 years old. He knew the psychological toll that prolonged lack of human contact could take from captains. The *Beagle*'s previous skipper had broken down and shot himself to death during the Southern Hemisphere winter of 1828, his third year away from home. Moreover, as Darwin himself affirmed in a letter to his sister, Fitzroy was worried about "his hereditary predisposition" to mental derangement. His illustrious

Captain Robert Fitzroy AMNH

uncle, the Viscount Castlereagh (suppressor of the Irish rebellion of 1798 and Foreign Secretary during the defeat of Napoleon), had slit his own throat in 1822. In fact, Fitzroy did break down and temporarily relinquish his command during the *Beagle*'s voyage—while Darwin was laid up with illness in Valparaiso.

Since Fitzroy was allowed no social contact with any of the ship's official personnel, he could gain it only by taking along a "supernumerary" passenger by his own arrangement. But the Admiralty frowned upon private passengers, even captains' wives; a gentleman companion brought for no other stated purpose

would never do. Fitzroy had taken other supernumeraries aboard—a draftsman and an instrument-maker among others—but neither could serve as a companion because they were not of the right social class. Fitzroy was an aristocrat, and he traced his ancestry directly to King Charles II. Only a gentleman could share his meals, and a gentleman Darwin surely was.

But how could Fitzroy entice a gentleman to accompany him on a voyage of five years' duration? Only by providing an opportunity for some justifying activity that could not be pursued elsewhere. And what else but natural history?—even though the *Beagle* had an official naturalist. Hence, Fitzroy advertised among his aristocratic friends for a gentleman naturalist. It was, as Burstyn argues, "A polite fiction to explain his guest's presence and an activity attractive enough to lure a gentleman on board for a long voyage." Darwin's sponsor, J. S. Henslow, understood perfectly. He wrote to Darwin: "Capt. F. wants a man (I understand) more as a companion than a mere collector." Darwin and Fitzroy met, they hit it off, and the pact was sealed. Darwin sailed as Fitzroy's companion, primarily to share his table at mealtime for every shipboard dinner during five long years.

Poor McKormick's fate was sealed. Initially, he and Darwin cooperated, but their ways inevitably parted. Darwin had all the advantages. He had the captain's ear. He had a servant. At ports of call, he had the money to move ashore and hire native collectors, while McKormick was bound to the ship and his official

duties. Darwin's private efforts began to outstrip McKormick's official collections, and McKormick, in disgust, decided to go home. In April 1832, at Rio de Janeiro, he was "invalided out" and sent home to England aboard H.M.S. *Tyne*. Darwin understood the euphemism and wrote to his sister of McKormick's "being invalided, i.e. being disagreeable to the Captain. . . . He is no loss."

Darwin did not care for McKormick's brand of science. He wrote to Henslow in May 1832: "He was a philosopher of rather antient [*sic*] date; at St. Jago by his own account he made general remarks during the first fortnight and collected particular facts during the last." In fact, Darwin didn't seem to care for McKormick at all. "My friend the doctor is an ass, but we jog on very amicably; at present he is in great tribulation, whether his cabin shall be painted french gray or dead white—I hear little except this subject from him."

If nothing else, this story illustrates the importance of social class as a consideration in the history of science. How different would the science of biology be today if Darwin had been the offspring of a tradesman and not the son of a very wealthy physician. Darwin's personal riches gave him the freedom to pursue research without encumbrance. Since his various illnesses often permitted only two to three hours of fruitful work per day, any need to make an honest living would probably have shut him off from research entirely. We now learn, from this tale of the *Beagle,* that Darwin's social standing also played a crucial role at a turning point in his career. Fitzroy was far more interested in his mealtime companion's social graces than his competence in natural history.

Might something deeper be hidden in the unrecorded mealtime conversations of Darwin and Fitzroy? Scientists have a strong bias for attributing creative insights to the constraints of empirical evidence. Hence, tortoises and finches have always received the nod as primary agents in the transformation of Darwin's world view, for he joined the *Beagle* as a naïvely pious student for the ministry, but opened his first notebook on the transmutation of species less than a year after his return. I would suggest that Fitzroy himself might have been an even more important catalyst.

Darwin and Fitzroy maintained a "rocky" relationship at best. Only the severe constraints of gentlemanly cordiality and pre-Victorian suppression of emotion kept the two men on decent terms with each other. Fitzroy was a martinet and an ardent Tory. Darwin was an equally committed Whig. Darwin scrupulously avoided any discussion with Fitzroy of the great Reform Bill then pending in Parliament. But slavery brought them into open conflict. One evening, Fitzroy told Darwin that he had witnessed proof of slavery's benevolence. One of Brazil's largest slaveholders had assembled his captives and asked them whether they wished to be freed. Unanimously, they had responded "no." When Darwin had the temerity to wonder what a response made in the owner's presence was worth, Fitzroy exploded and informed Darwin that anyone who doubted his word was not fit to eat with him. Darwin moved out and joined the mates, but Fitzroy backed down and sent a formal apology a few days later.

We know that Darwin bristled in the face of Fitzroy's strong opinions. But he was Fitzroy's guest and, in one peculiar sense, his subordinate, for a captain at sea was an absolute and unquestioned tyrant in Fitzroy's time. Darwin could not express his dissent. For five long years, one of the most brilliant men in recorded history kept his peace. Late in life, Darwin recalled in his autobiography that "the difficulty of living on good terms with a Captain of a Man-of-War is much increased by its being almost mutinous to answer him as one would answer anyone else; and by the awe in which he is held—or was held in my time, by all on board."

Now Tory politics was not Fitzroy's only ideological passion. The other was religion. Fitzroy had some moments of doubt about the Bible's literal truth, but he tended to view Moses as an accurate historian and geologist and even spent considerable time trying to calculate the dimensions of Noah's Ark. Fitzroy's *idée fixe,* at least in later life, was the "argument from design," the belief that God's benevolence (indeed his very existence) can be inferred from the perfection of organic structure. Darwin, on the other hand, accepted the idea of excellent design but proposed a natural explanation that could not have been more contrary to Fitzroy's belief. Darwin developed an evolutionary theory based on chance variation and natural selection by a largely external environment: a rigidly materialistic (and basically atheistic) version of evolution (see my column of December 1974). Many other evolutionary theories of the nineteenth century were far more congenial to Fitzroy's type of Christianity. Religious leaders, for example, had far less trouble with common proposals for innate perfecting tendencies than with Darwin's uncompromisingly mechanical view.

Was Darwin led to his philosophical outlook partly as a response to Fitzroy's dogmatic insistence upon the argument from design? We have no evidence that Darwin, aboard the *Beagle,* was anything but a good Christian. The doubts and rejection came later. Midway through the voyage, he wrote to a friend: "I often conjecture what will become of me; my wishes certainly would make me a country clergyman." And he even coauthored with Fitzroy an appeal for the support of Pacific missionary work entitled, "The Moral State of Tahiti." But the seeds of doubt must have been sown in quiet hours of contemplation aboard the *Beagle.* And think of Darwin's position on board—dining every day for five years with an authoritarian captain whom he could not rebuke, whose politics and bearing stood against all his beliefs, and whom, basically, he did not like. Who knows what "silent alchemy" might have worked upon Darwin's brain during five years of insistent harangue. Fitzroy may well have been far more important than finches, at least for inspiring the materialistic and antitheistic tone of Darwin's philosophy and evolutionary theory.

Fitzroy, at least, blamed himself as his mind became unhinged in later life. He began to see himself as the unwitting agent of Darwin's heresy (indeed, I am suggesting that this may be true in a more literal sense than Fitzroy ever imagined). He developed a burning desire to expiate his guilt and to reassert the Bible's supremacy. At the famous British Association Meeting of 1860 (where Huxley creamed Bishop "Soapy Sam" Wilberforce), the unbalanced Fitzroy stalked about, holding a Bible above his head and shouting, "The Book, The Book." Five years later, he shot himself.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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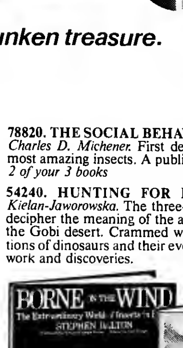

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Slow Exodus From Mesa Verde

by Douglas Osborne

A deteriorating environment and prolonged droughts gradually forced the Pueblo Indians from their thousand-year-old homeland

The Pueblo Indian abandonment of the vast area known as the Four Corners, where New Mexico, Arizona, Utah, and Colorado join, is one of the most intriguing and perplexing human movements in this continent's prehistory. After about A.D. 1300, the area was almost totally devoid of Pueblo agriculturists, but the ruins of their homes and religious structures and remnants of their agricultural and water control efforts have been found by the tens of thousands. Yet, strikingly, Pueblo Indians had lived here for as long as a thousand years.

Evidence exists for human occupation of the area as far back as 5000 B.C. At the beginning of the Christian Era, or shortly thereafter, a semisedentary people, the Anasazi, or Ancient Ones, were already living in much of the region. By the sixth and seventh centuries, this population had greatly increased. These people, the ancestors of the Pueblos, were designated by archeologists as Basket Makers because of their prowess at basket making. Like many of their predecessors, they lived in pit houses (semisubterranean dwellings), and most importantly, they exhibited the basic attributes of the Pueblo pattern of agriculture. They had well-developed ceramics and had adopted the bow and arrow to replace the atlatl, or spear thrower, and dart.

This late Basket Maker period merged into the first Pueblo period (ca. 700 to 900), which was characterized by a sharply expanded population, increased dependence on agriculture, and partial to total use of earthen or earth- and stone-walled structures built on the surface of the ground. In some settlements the people continued to use pit houses as religious or ceremonial quarters, but others had more specialized underground ceremonial rooms—pit houses that had evolved architecturally in the direction of true kivas, or Pueblo religious chambers.

The next 200 years was a time of continued population increase. As architectural design became more elaborate, multifamily dwellings, some of great size, were built of stones that had been partly shaped. Agricultural practices attuned to the various local environmental situations were carried out with increasing efficiency, and water control projects were regularly undertaken.

At Mesa Verde in southwest Colorado, a large number of small stone-and-earth dams, placed across intermittent drainage ways, have been dated to this time. Only a few feet high and usually showing an upstream tilt, these dams successfully retarded water flow off the mesa. They also trapped small deposits of sediment that acted to retain rainfall. The moist soil in these areas was thus excellent for agriculture. The dams, many of which have endured to this day with only slight wear and tear, were no doubt important in the retention of soil at Mesa Verde and, hence, in its present fertile appearance.

On the larger mesas and near the larger archeological sites, remains of actual reservoirs with tributary and distributary ditches have been found. These were apparently not used as sources of irrigation water but rather for household supplies. Such developments in socially oriented technology may indicate that increasing populations and uncertain natural water supplies created demands unknown in earlier times.

The last Pueblo period of cultural differentiation in the Four Corners began about A.D. 1100 and lasted until about 1300. During this time shaped stones were used to construct well-built structures. Most of the houses had from fifteen to twenty rooms, but some had hundreds of rooms. Each room may have housed an individual kinship group. The larger pueblos, those with many kivas, suggest an agglomeration of kin groups, each with its own ceremonial quarters.

Over the space of a thousand years, then, subsistence and cultural patterns of the Pueblos and their ancestors became increasingly sophisticated. Why, then, did these people abandon their settlements and disperse to the south? Based on excavations at Wetherill Mesa in Mesa Verde National Park, archeologists believe one probable reason for the shift was changing climate.

Fortunately for climatologists and archeologists, the study of growth patterns in trees can tell a great deal about climate. In the American Southwest, tree-ring records are the clearest and have the greatest time

Archeologists first thought towers like those at Mesa Verde's Cliff Palace served a military function. Now, they are believed to have had a religious purpose.

David Muench

Situated atop Mesa Verde, Far View House comprises more than 75 rooms and 5 kivas. Dated to between A.D. 1100 and 1200, this structure was built when most Pueblos were moving from arable land to cliff bases.

David Muench

depth, and the timbers found so often in Indian ruins can be used to date past events. We are thus able to offer a brief sketch of past climate of the Mesa Verde.

Although precipitation there now averages about eighteen or nineteen inches per year, the evidence reveals that from the fifth to the seventeenth century A.D. there were eleven or twelve severe droughts. Until the tenth century there was great climatic variability, with some severe dry periods. But these were not harsh enough to relax the people's hold on the land, and it was probably during this time that the techniques of dry farming and water control were developed.

The last Pueblo period at Mesa Verde opened with a dry period. The climate then improved until the late 1200s when another drought occurred. It lasted, with a slight intermission, from 1273 to 1285 (tree-ring dating is that exact) and must have been instrumental in giving the coup de grâce to Pueblo Indian culture in this part of the country.

Previous droughts apparently had not been severe enough to uproot the Indians, but their cumulative effects did force the people to adopt an agricultural pattern peculiar to the area. More than the dry periods themselves, it was these compensating techniques that finally altered the land and made habitation impossible.

Agriculture in the dry plateau country of which Mesa Verde is a part has always been marginal. It is so even today for the modern farmers in the nearby countryside. The pendulum swings between droughts and floods. Agricultural uncertainty was the over-all fact of life for the Pueblo farmer. The fear that winter snowfalls might be insufficient to keep the ground moist for spring planting or that July and August rains necessary to mature the corn might fail is generally believed to underlie the development of Pueblo Indian religious observances, with their strong emphasis on inducing rain.

The Pueblo farmer had no domesticated animals to help him. He cleared land with stone tools and fire and loosened the soil with digging sticks. He planted maize, beans, and squash in holes made with planting sticks and weeded with a stone-shod thrusting hoe or, more usually, a wooden weeding sword.

Farming and the need for firewood required that the land be cleared, but this exposed to erosion the fragile topsoil on the Wetherill Mesa, much of it of eolian origin. The area of intensive farming was the broad, flat central part of the mesa, which had the best soil, more moisture, and a long frost-free growing season—and where the best forest now grows. Terracing, small dams, and temporary wood or brush checks built across the gullies were the farmers' best answer to erosion and rapid runoff. We have no better one today. Seventy-five percent of these checks, or farming terraces, have been found on the east–northeast sides of the mesa where canyon slopes are less abrupt. Here the northerly sun of spring melted the snow slowly, allowing it to soak into the soil, and the morning sun in summer made the corn shoot up.

Such measures, however, could only temporarily halt soil movement, not prevent it. During heavy rainstorms and sudden snowmelts, soil washed over the cliffs. Over the centuries soil also rapidly built up behind the checks. The top foot of soil behind these dams contains no pollen of cultivated plants, hence it must have been deposited after farming ended there about A.D. 1300. Yet, soil deposits several feet thick lying beneath the upper layer do contain agricultural plant pollen, in addition to potsherds and other archeological evidence of activity. If the dams were built 300 to 400 years before 1300, then it is apparent that erosion and deposition were rapid while the land was under cultivation.

After the Indians left and the forests returned, soil wash slowed remarkably. During the almost 700 years since abandonment, only one foot of soil has accumulated, whereas before abandonment, from two to four feet of soil was deposited in perhaps half that time, or about 350 years. Extensive environmental damage thus took place in spite of the people's intelligent attempts to stop it. This was presumably also true in other Pueblo settlements.

Soil loss and drought would logically result in poor crops. I think we have evidence of this, but it is a matter of interpretation, not of firm proof. Corn plant remains found at Wetherill Mesa were certainly not excellent examples of the aridity-adapted strain of corn that these people planted. At Mug House, a pueblo with a major late occupation on the west side of Wetherill Mesa, the ears of corn were small and often misshapen, and squash remains were from immature fruits. These observations may reflect no more than the results of a selection process by the Mug House people or they may indicate the effects of dryness and poor soil on their crops in the latter days. The Mesa Verde people may have taken most of their food with them when they left the area, for we have no selected and stored foods for study.

The corn remains found near Step House on the eastern rim of Wetherill, however, showed that the plants had been healthy. But then the eastern and northeastern parts of the mesas are moister and better for farming. We cannot be sure that the Step and Mug House corn remains were of the same years. They probably were not, but I think they do give us an understanding of the problems of the Pueblo agriculturists—some had food, others did not. We must remember that these people were almost certainly organized by kinship, rather than by territory; therefore, it is doubtful if any mechanism existed to share food or gather provisions for a stricken area. Jealousy, accusations of witchcraft, even raiding and thieving could have resulted if the food situation became dire for a Pueblo. Such actions could have led to cultural fragmentation and ultimately to abandonment.

Even if crops were successful, a population increase during the last Pueblo period may have produced food scarcity and contributed to the eventual migration. The population of Mesa Verde is difficult to estimate. Not all sites can be excavated. Ar-

Only men were permitted to enter kivas—Pueblo religious structures. The Indians believed their ancestral spirits emerged through the round holes found in the floors of most kivas.

David Muench

cheologists must therefore estimate population on the basis of room numbers in the sites that have been excavated or examined.

On this basis, the sites of the earliest Pueblo period, according to the archeological survey of Wetherill, had 1,166 rooms. During the early phase of the next period, the sites had 1,248 rooms, but this number later declined to 996. The last period had only 540 rooms in its earlier phase, but the number rose to 1,512 in the late and last period of occupation. These figures are obviously strongly influenced by the fortunes of archeological surveys. More sites and rooms were found from the latest times. When the Indians departed the area, they left their structures intact, while dwellings from earlier periods were all subject to reuse and rebuilding.

Of the 1,512 rooms, we estimated that about 1,000 rooms may have seen concurrent use. Slightly over one-fourth of these, however, were for storage. Some 700 rooms were thus lived in. If we accept a one person–one room ratio, more than 700 persons lived within the ten-square-mile area of Wetherill Mesa in the 1200s. This is a heavy burden for marginal farming land to bear and must have placed the dwellers in a risky situation.

Throughout the occupation of Mesa Verde, the Indians shifted their dwelling sites. During the early Pueblo period, 91 percent of the sites were concentrated in the most fertile areas on the broad mesa tops. Only 9 percent were located on the mesa's talus slopes and in the overhangs and caves of the cliffs. During the early years of the next occupation, however, the talus slope and cliff dwellers increased to 18 percent. And later in this period more than half the sites were in these areas. The progression continued during the last occupation, so that by 1200 only 25 percent of the dwellings were on the mesa, 19 percent were on the talus slopes, and 66 percent in the cliffs.

The nature of the phenomenon indicates the movement was a continuing answer to a growing problem. It may be that soil loss and consequent decrease in fertility prompted the Indians to convert most of the mesa tops to farmland. Alternatively, the talus slopes and canyon bottoms, now enriched by the soil that washed off the mesa, may well have become better cropland. In either case the answer revolves around environmental destruction and soil loss.

Large population groupings were not new to these people. Some earlier Pueblo sites, although not on Wetherill Mesa, suggest that the process of agglomeration was an old one. But these people were not squeezed into alcoves in cliffs as were the people around Wetherill Mesa. One possible repercussion of the crowded conditions was a short life expectancy for females—a possibility strengthened by the results of ethological studies showing that crowding decreases female life expectancy in several mammalian species. Skeletal studies at Mesa Verde show that the average life-span for women was from 20 to 25 years whereas for men it was from 31 to 35 years.

These early deaths may have been one of the most obvious manifestations of the pressures wrought by environmental conditions. But there may have been another and more subtle factor influencing the conditions under which the later Pueblos existed—their eventual lack of ability to adapt. Whereas the earliest Pueblos of A.D. 800 were able to alter their architecture, their religious and social lives, and many aspects of their material existence, the Indians of the thirteenth century appear to have lost this adaptability. The architecture continued to change, as did the ceramics; artistically and technologically sophisticated pots of many styles were common during all of the latter periods. But farming and hunting tools, clothing, and even much of the ornamentation, were set in a mold early, and later changes were unusual. There is evidence that a superior variety of corn was being grown in late times but it was rare.

Agricultural tools were essentially of the same design as they had been in the 600s among the Basket Makers. For a time, the later Pueblos experimented with thrusting hoes shod with stone or mountain sheep horn as blades, but these were abandoned. Clothing was adequate but rarely decorative and the techniques of making clothing had not changed since the early days. The solidly twilled sandals of the 1200s, while strong and serviceable, were crude compared to the twined ones of a thousand years earlier.

The people living at Mesa Verde during the twelfth and thirteenth centuries give the impression of being self-contained, efficient, and rather drab. At the same time, they were losing the struggle to stop soil loss; very possibly insects were also ruining a fair share of the corn harvest. The rain dances and the prayers were consistently ineffectual in the dry years toward the end of the thirteenth century. The use of fertile mesa top areas, at the sacrifice of living in crowded conditions, probably did not increase food production for families. The dryness and constant hunting pressure had driven the animals into the mountains where even the best bowman or the most cunningly placed snares could not often get meat. Women, even girls, were wrapped in their sleeping mats and feather cloaks and placed in their graves, one after another.

We can never know how the Pueblos analyzed the situation. They certainly must have recognized the implications of enduring drought, poor soil, and inadequate food. Early sites a few hundred miles to the south of Mesa Verde contain architectural and ceramic styles typical of the mesa and suggest a Pueblo inclination toward this direction from the north. If we follow the Indians' route correctly, they moved slowly, building fortified villages in nearly impregnable areas, making and breaking their distinctive pottery, mixing with other peoples, and, finally, as the generations slipped by, becoming a part of the great block of Pueblo people that stretched from Taos in the upper Rio Grande Valley west to north-central Arizona where the Hopi Indians lived. Perhaps the necessity for this movement carries a message for us today. □

Two varieties of corn were raised at Mesa Verde; one had fuller, larger kernels than the other. Archeologists do not know why the Pueblos did not plant the superior variety with greater frequency.

David Muench

The Image Makers of Nepal

by Alexander Duncan photographs by James Kittle

Casting statues by means of the lost wax process produces art works of infinitely fine detail

The art of casting images in metal has been practiced by Nepalese sculptors since at least the seventh century. The Nepalese learned the technique from the Indians and, in turn, passed on their knowledge to the Tibetans. From these ancient beginnings, the Nepalese tradition of metal casting has continued to the present day, uninterrupted by the various upheavals that disturbed the artistic traditions of India, Tibet, and China.

In Nepal, image casting has long been the occupation of the Sakyas, a caste of the Newars of the Kathmandu Valley, Buddhists who trace their ancestry to Lord Buddha himself. Although the Sakyas are distributed in all three of the major towns of the valley (Kathmandu, Bhaktapur, and Patan), the families engaged in metal casting are concentrated in Patan, "the City of Fine Arts." In Patan itself, they are further concentrated in two Sakya "bahals," or quasi-monastic communities, consisting of houses clustered around a central temple. In these several-storied Newar houses, famous for their elaborately carved windows and doors, the ancient tradition of image casting is kept alive. Here master sculptors knead beeswax with their fingers and splinters of buffalo horn and pour molten metal into simple clay molds to produce sculpture of beauty and grace and often of a complexity that astonishes Western founders using far more sophisticated techniques.

The images these artists create are all icons—statues of Buddhist and Hindu gods and holy men, largely Buddhist because all of the artists are Buddhist. The images, varying in size from several inches in height to more than life-size, are fashioned according to strict rules of iconography, which determine form, posture, attitude, and dress. These rules limit, but do not negate, the artist's creativity, for the challenge of Asian religious sculpture lies in bringing these ancient canons to life in an image of transcendental beauty. A good sculptor's interpretation of his subject will always surpass in grace and liveliness that of a mediocre artist, and the contrast will be apparent even to the casual observer.

The sculptors of Nepal use the lost wax process (cire perdue), which is generally considered to yield the finest results although it is considerably more painstaking than other techniques. Briefly, the lost wax process consists of the making of a wax model (which melts readily at a high temperature but keeps its shape when exposed to the moderate warmth of a summer day), encasing the model in a fire-resistant mold, drying the mold, and then heating it in an oven or over a fire until the wax melts out of a small hole left in the mold, hence the name lost wax. Molten metal is then poured into the vacant space, taking the form of the original wax sculpture. When the metal has cooled and hardened, the clay mold is broken and the sculpture emerges in metal. With the lost wax method, there is no possibility of mass production because the casting mold must be broken and cannot be reused; in order to reproduce the sculpture, an entirely new wax model must be fashioned. This technique produces the best results, for if a very fine clay is used for the interior surface of the mold, all of the intricate details sculpted in the wax will be transmitted to the metal without distortion. Such detail is impossible to produce with reusable casting molds.

The first step of this process, the fabrication of the sculpture in wax, is the most important from the creative point of view. This is the actual act of sculpture, and the rest of the process is devoted to the faithful transmutation of the original sculpture into another material, metal. In modern Western sculpture, the sculptor often does not concern himself with the rest of the process beyond the actual sculpting. A Western sculptor will usually model his sculpture in a material such as clay or plaster; then give it to a founder, whose job it is to reproduce the original, first in wax and then in metal. In Nepal this distinction between the artist (the sculptor) and the craftsman (the founder) does not exist; almost all of the Nepalese image sculptors cast their own work, although they are not involved in the final finishing and engraving.

The casters use several different metals; the most common of these are copper and brass, although bronze, German silver (a nickel alloy), iron, and silver are also cast. Each has its advantages and drawbacks: copper is soft and easy to work with once cast, but it has a high melting point and does not flow easily; brass flows better, has a lower melting point, and is cheaper, but it is not as attractive a metal as pure copper; bronze (in Nepal, a pure alloy of copper and tin)

Jewel-encrusted face of a fierce Buddhist deity.

flows readily, but it is brittle and often breaks during finishing. The other metals are used only infrequently on special orders. The casters do not usually mix their own alloys but purchase them in the form of scrap from the metal market in Kathmandu.

The Nepalese sculptor is generally commissioned to start a new work by a client, usually a shop owner who wishes to sell the sculpture in his shop or a religious Nepalese who wishes to use the image on his household altar; sometimes the sculptor receives a commission from a community that wants an image for a temple. The two latter forms of patronage were the only source of income for the sculptors of ancient times, but the dominant source of income for most of today's sculptors is the patronage of businessmen who sell images to tourists. Although this rise in the demand for sculpture has had a somewhat deleterious effect on the finishing of many of the cheaper images, it has had a tonic effect on the sculptors themselves, who are now constantly employed and are thus able to sharpen their skills.

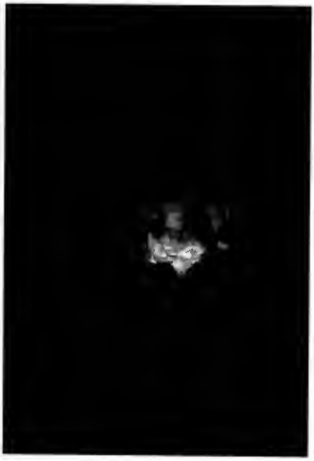
Once the sculptor has received a commission, and the subject, size, and price have been agreed upon, he starts his work with a lump of raw casting wax—a combination of beeswax, resin, and ghee (clarified butter)—which he must shape into the form of a god or goddess. To do this, he uses primarily his fingers and a few rudimentary tools: a few bone and steel tools for shaping and scraping and a charcoal brazier to heat and soften the wax. The medium is pliable and will hold fine detail, but it is by no means easy to work, as I have discovered myself while attempting a sculpture. In inexperienced hands, the wax, which seems to take shape of its own accord under the practiced fingers of a master, becomes sticky and intractable, producing a feeling of frustration in the beginner.

Lost wax sculpture is cast either solid or hollow, depending on the size of the image. The Nepalese sculptors cast their images hollow, with the exception of very small, seated figures and standing figures of up to twelve inches in height. If the figure is to be cast solid, the sculptor will usually make the original model of solid wax. If it is to be cast hollow, he makes the wax hollow, the thickness of the wax being determined by the final thickness of metal desired in the casting, usually one-eighth to one-fourth of an inch.

Once the wax figure is completed, a mold is taken from it if additional copies of the same sculpture are desired. This is done by pressing a softened wax of a slightly different composition against the surface of the sculpture, thereby producing a negative mold. Several molds are used to reproduce one sculpture, for example, one mold for the face, another for the torso, several more for arms, legs, and so on. Pressing warm, pliable sheets of wax into these molds, the sculptor can obtain reproductions of the originals, and by fitting these together, he can produce a second wax the same as the first, making it unnecessary to repeat the entire process of sculpting the image from raw wax. Since many of the statues are popular items in the curio shops, this is done with any sculpture the artist feels will be reordered. It must be emphasized that reproduction through the use of wax molds is different from reproduction through the use of reusable casting molds, for the wax must still be assembled anew and a fresh casting mold made.

Before the completed wax sculpture is covered with clay, the caster adds several wax pipes, culminating in a small wax funnel, to the bottom of the image. (Later, when the wax has been melted out, the space occupied by the pipes will form conduits through which the molten metal will be poured.)

The next step in the process is the fabrication of the clay casting mold. This is the longest step in the entire



Pieces of copper wire and sheeting are melted in a coal-fired furnace.

The caster lifts the crucible with tongs so that more coal can be added to increase the heat. Before receiving the molten metal, molds are heated in an oven for several hours.

procedure, for the molds must dry evenly in the sun and the sculptor is at the mercy of the weather. For small sculptures the mold may take only one week to dry in sunny weather, but large and complex images may take as long as three or four months. The first layer to be applied is a mixture of equal parts of a fine gray clay and cow dung, which prevents the clay from cracking while drying and gives porousness to the mold when it has been burned out prior to casting. The wax statue is dipped in a relatively thin solution of this clay-dung mixture so that a coating of perhaps one-half inch adheres to the outside and inside (if hollow) of the wax. Once this first layer has dried, another layer is applied in the same way. At this point, if the casting is hollow, several nails are driven through the wax, so that when the mold has been completed one-half of a nail will be embedded in the clay core inside the image and the other half in the clay coating on the outside; when the wax is melted out, these nails will prevent the core from slipping inside the mold and damaging the casting.

The final applications are of a coarser, yellow clay mixed equally with rice husks, which serve much the same purpose as the cow dung in the first mixture. This clay is applied as a paste in one-inch layers; usually two or three applications are necessary, and each layer is allowed to dry before the next is applied. With the last of these applications the mold is complete; in most cases it is from two to three inches thick.

The mold materials used by the Nepalese are very simple and are found in various locations throughout the Kathmandu Valley. The two types of clay are provided by peasants who have an arrangement with the casters to bring them the clay from their fields. The rice husks are also purchased from peasants or from rice mills, while the cow dung is provided by the numerous cows wandering the streets.

Despite the simplicity of these materials, the molds are very strong, far stronger than the plaster molds often used in the West. The fine clay, if properly prepared, is also extremely faithful in recording the details of the wax. It is not unusual to be able to see the sculptor's fingerprints on the surface of the final casting.

After the mold is finished, the wax is melted out over a slow fire through the opening left for this purpose. The melted wax is allowed to drip into a pan of water, from which it is collected to be used again. When all the wax has been melted out, the mold is ready for casting, which usually takes place the next day. Although this step in the process is simple and takes little time or skill, it is perhaps the most symbolic moment of the entire technique, for it is at this point that the wax is "lost." All the days of painstaking sculpture are gone, having leaked out of the mold's aperture as drops of melted wax, and it is only the empty shell of clay that holds the promise of the rebirth of the image in metal. It is this sense of emptiness giving birth to form that gives metal casting its peculiar fascination.

The day of the casting is the climax of an effort that has taken anywhere from a few weeks to several months. In Nepal it is an exciting day with several people on the scene, each with a job to fulfill. Perhaps it would be best to describe in detail the event as it takes place in a typical caster's workshop.

The image to be cast on this day is a sixteen-inch sculpture of Vajra Sattva, a two-armed Buddhist bodhisattva seated in a graceful posture on a lotus throne, sculpted by one of the finest of the Sakya casters of Patan.

The day begins when the master sculptor comes into his workshop, a small shed on the bottom floor of his house, to prepare for the casting. The necessary materials are brought in: wood for the oven where the mold will be heated, enough coal to melt the copper in which the image will be

When the molds are sufficiently hot and dry, the caster begins to pour the molten metal.

The moment of pouring is a crucial one; the copper must flow smoothly into the molds.

The molds are left to cool. There is no way to anticipate the final result of the casting.

cast, the crucible, various tongs, and the metal itself in the form of old copper wire and sheeting, which has been purchased in the market in Kathmandu. The copper is weighed out on a balance scale; using the weight of the original wax image multiplied by a factor of eight, it is estimated that the Vajra Sattva will require about thirteen pounds of metal, and this is kept aside.

The wood in the mold oven is lighted and a low fire is built up; then the mold of the Vajra Sattva, emptied the previous night, is gently placed inside and the oven opening is walled up with tile and bricks. The mold will stay in the oven for about two and a half hours to insure that the last vestiges of wax are burned out and that the mold will be totally dry and hot when the metal is poured. If the mold is too cool at the time of casting it may crack or cause the metal to cool too fast, resulting in a damaged casting.

After the oven fire has been satisfactorily lighted, the caster, now assisted by his eldest son, turns his attention to the melting furnace. The furnace is a simple affair, a three-foot-high, welllike cylinder of bricks plastered with mud, with a grate just above the floor and an opening at the bottom through which air is forced by means of an Indian-made mechanical bellows. This bellows, turned by hand, is the only mechanical device used during the entire procedure; with this sole exception, the casting workshop resembles in every detail that of the caster's grandfather.

A thin layer of lit charcoal is placed at the bottom of the furnace; above this is placed the crucible, surrounded by coal. About half of the entire charge of copper is placed in the crucible, and the furnace opening covered with a few clay tiles. The son then starts the wearying job of cranking the bellows, one of the chores of his apprenticeship. After a few minutes, the coal catches and a hot fire sends tongues of flame up around the tiles covering the crucible.

For the next hour or so the master relaxes while his son keeps the fire high in the furnace. His wife brings him a hookah, which he puffs on while watching the flames from the two fires. Occasionally he adds a few sticks to the oven, making sure that the fire remains even. After perhaps forty-five minutes, the flames issuing from the furnace begin to take on a greenish tinge as the copper melts and oxidizes. When the metal is completely melted, the caster removes the tiles and stirs the metal with an iron rod. Lifting the crucible with a pair of tongs, he holds it up while his son jabs at the coals and adds fresh coal to the fire. Before replacing the tiles, the remaining copper in the charge is added to the crucible.

Again the master sits back for a brief rest. At this point his wife, who also plays a part in the casting, brings in a large earthen bowl of water, in which the mold will be cooled after the metal has been poured. While his son is still hard at work keeping the furnace fire hot, the master prepares the area where the mold will be placed, piling a few bricks to support the clay of the mold against the pressure of thirteen pounds of molten copper. His wife hands him a long strip of thick cotton material, which he winds around his waist and right arm to protect himself from the heat of the crucible and from any molten metal that may spill. Other than this, he takes no precautions against accidents and casts in his bare feet.

By watching the flames shooting from the furnace, which have now become bright green, the caster ascertains that the metal is ready to be poured. He pulls the tiles from the top of the furnace and inspects the metal, stirring it with the iron rod. The copper is completely melted and stirs easily. The time has come for the casting. Turning to the mold oven, the caster carefully removes the bricks and tiles from the front. Inside the oven the mold glows a light cherry red. Very gently, the caster picks up

Water is used to help cool the mold so that the sculpture may be freed from its casing. Gently tapping the mold with a short iron rod, the caster cracks the wet clay.

This is the moment when the success or failure of the casting will be evident.

the mold with a pair of long tongs and transfers it to the pile of bricks selected as the spot for pouring. Using the cloth on his hands for protection, he carefully shifts the mold to a good position, where it is upright and well supported.

The caster now looks down the mold aperture, called the pour, to check the heat of the mold. Seeing that the inside of the mold is a bright cherry red, he decides to delay for a few moments the removal of the crucible from the furnace, for if the mold is too hot, the metal may "boil" when it is poured, causing a pitted casting. This is the moment when beginning casters often make mistakes, for the tenseness of the situation encourages haste, which is often neither necessary nor desirable. A good casting depends on speed at the right moment and an ability to ascertain the right moment through an accurate judgment of the temperature of both mold and metal. Whereas a beginner may get flustered, an experienced caster always acts deliberately.

When the mold has cooled slightly, the caster, using another set of tongs, grasps the crucible and levers it out of the furnace. Placing it on the ground next to the mold, he tilts it to one side while his son scrapes floating dross and bits of coal from the gleaming surface of the molten metal. Then the master hoists the heavy crucible and very slowly tilts it over the pour, so that the molten copper flows evenly and smoothly into the mold. While the metal is flowing, the son pitches small bits of wax into the pour, which ignite as they touch the hot metal. The flames thus produced help to keep the metal from cooling too fast and clogging the mold. Within a few seconds the mold is full and the metal backs up into the pour opening. The casting is now finished. The remainder of the copper is poured into a small piece of clay, the crucible is laid in a corner, and everyone sits down to wait while the mold cools.

At this point there is no way to tell how the casting will come out. There were no cracks in the mold and the metal did not bubble as it was being poured—these are good signs, but not conclusive. So the waiting has some suspense, for although the master has completed many castings, each represents a great investment of time and energy in sculpting and making the mold, and a ruined casting means work that must be done over again.

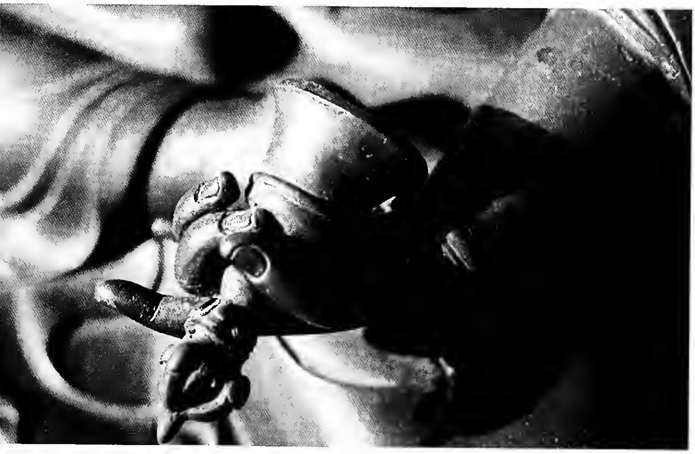
After standing a few minutes, the mold is gently laid in the large earthen bowl of water brought by the master's wife. Immediately, the water begins to boil and bubble and clouds of steam fill the workshop. The master's wife now pours water from a bronze pitcher over the mold and as the mold cools and becomes possible to touch, she turns it in the bowl so that all parts are cooled. After a few minutes of immersion, the boiling subsides and the caster lightly taps the clay covering the head of the image with a short iron rod. The wet clay cracks and falls away, revealing the gentle smile and downcast eyes of the god. The face is perfectly cast. More eagerly, the sculptor knocks off the clay from the rest of the image, and bit by bit, the torso, arms, legs, and lotus base emerge in the iridescent rainbow hues of freshly cast copper. It is at this moment that the magic of metal casting is strongest. The god's figure, first seen a month before in the dull gray of the wax, then covered over with successive layers of clay, finally reappears—like a butterfly emerging from a chrysalis—in its new and beautiful garb. The casting is perfect, unusually so, for large copper castings almost always have a few defects, and this Vajra Sattva has none. The suspense of waiting is replaced by happy relaxation, and while the caster enjoys a drink and a hookah of fresh tobacco, the image is set against a wall to be admired.

When the casting is finished, the job of the sculptor-caster is over, and the statue is passed on to the engravers, also members of the Sakya caste,

Completely freed of its clay covering, the perfect image reflects the skill of the caster.

The task of finishing and smoothing the statue is handed over to other artisans.

Engravers add intricate details that were not included in the original wax sculpture.



A popular Buddhist deity, the Vajra Sattva is depicted holding two associated symbols—the bell (shown in detail, bottom left) and the sacred thunderbolt. The detail at top left features a hand grasping a lotus stem, another major Buddhist symbol.

who smooth the surface of the casting and engrave any details that are too fine to be included on the original wax. The quality of engraving in Nepal varies greatly. Since the production of statues has multiplied greatly due to the influx of tourists, many engravers work too quickly, and their haste is reflected in the finished statue. But there still exist engravers of exceptional talent, and when they apply their skills to a well-sculpted and well-cast piece, the final product can be breathtaking.

If the image was cast in copper, the final step in the finishing process is often gilding. This is done by the mercury process, an art now lost to the Western world. The image is first dipped in a weak acid bath to clean its surface. Then an amalgam of mercury and gold is applied over the surface that is to be gilded. When the image has been evenly coated with the amalgam, it is placed over a smokeless fire and the mercury boils off, leaving a thin layer of pure gold adhering to the copper. Because the mercury fumes created during this process are extremely dangerous, the craftsmen are careful to stay upwind from the fire, which is never placed in an enclosed space. This danger is one reason that mercury gilding is no longer practiced in the West, and despite the precautions, many of the men who work with this process in Nepal fall sick from mercury poisoning. The result obtained by mercury gilding, however, is far more pleasing than the modern technique of electroplating; the mercury process leaves a rich, warm coating of gold that electroplating cannot achieve.

The Nepalese sculptors show very broad taste in the styles they choose for their pieces, and sculpture from several traditions—Indian and Tibetan, as well as Nepalese—issues from their workshops. The sculptors of Asia have always been influenced by the past, employing earlier sculpture as models for their own, and the same is true for the sculptors of modern Nepal. They have a vast variety of previous work from which to choose, and with so many books on Asian art available, they can pick as a model an image that may reside in a distant museum. In general, they seem to prefer the imagery of the more recent past; more than half the work produced by the community of sculptors resembles the later, more heavily ornamented pieces produced in Nepal and Tibet during the eighteenth and nineteenth centuries. But other, older styles also serve as inspiration, and one caster even produces bronzes in the Greco-Buddhist style of Gandhara stone sculpture.

What is the future of these Nepalese image casters and the tradition they uphold? There are some who fear that the pressures of modernization at work in Nepal will eventually destroy this art, but this seems unlikely. The most important factor in the survival of this Nepalese art is the strong cultural and religious identity of the Sakya Newars who practice it. Although they take what is useful from what they see in Western technology and values, they show no inclination to abandon the traditions that have made them such a highly civilized people. This solidarity applies not only to the older generation but to the younger as well, and many of the sons of master sculptors are following their fathers' vocations. If these coming generations of Nepalese sculptors show the talent and dedication displayed by their forefathers, the future of image casting in Nepal is secure. □

Black Bears of the Smokies

by Michael R. Pelton and Gordon M. Burghardt

Tourists, hunters, and poachers make the Great Smoky Mountains National Park a precarious sanctuary for the adaptable black bear

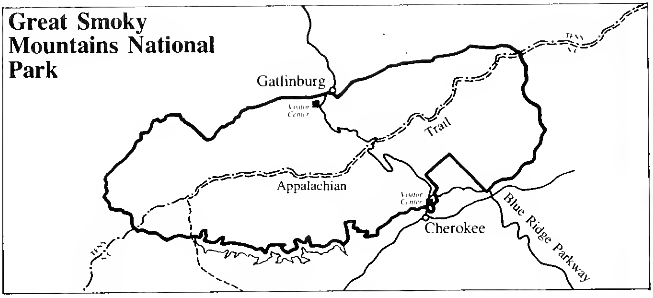
The black bear, *Ursus americanus*, and the remaining wilderness of the eastern United States have become so symbolically intertwined in the mind of the public, that few people realize that the black bear has one of the widest distributions of any large mammal in North America. The animal can still be found in the swamps of the South, the White Mountains of New England, the Adirondack and Catskill mountains of New York, the Blue Ridge of the Virginias, and the Great Smokies of Tennessee, the Carolinas, and Georgia. The black bear still stalks the northern hardwood forests of the upper Midwest, the boreal forest in Canada and Alaska, and the mountainous areas west of the Mississippi River.

These areas differ dramatically in climate, vegetation, and habitat, but *U. americanus* has evolved appropriate adaptations to enable it to live under such diverse, even extreme conditions. In the East, however, the popular association with remnant wilderness is valid because human intrusions into former habitats have forced the species to recede into smaller and smaller enclaves.

The adaptations that enable the black bear to succeed in different en-

Black bears are surprisingly fast. The shy animals also possess keen smell and hearing, senses that are useful in avoiding humans.

Arthur Swoger



vironments can be understood, at least in part, by studying the animal in such representative aboriginal habitats as national parks and other large protected areas—with the added benefit of gaining information about the nature of human–bear interrelationships. Such information is extremely important if we are to provide sufficient protection to the remnant black bear populations in the East.

With this in mind, we conducted an ecological and behavioral study of the black bear in Great Smoky Mountains National Park—a rugged 800-square-mile area, in which narrow valleys cut deeply into an uninterrupted mountain chain with elevations of 5,000 to 6,500 feet. Average annual precipitation ranges from fifty to sixty inches in the lower valleys, eighty to one hundred inches at higher elevations. As a result of topography and precipitation, dense forests dominate the area, and the presence of food-producing trees, bushes, and other plants makes most of the parkland excellent black bear habitat.

Until settlers arrived in the Smoky Mountain country in the 1790s, hunting by Indians was the only significant influence on the black bear. By the mid-1800s, however, all the major valley bottoms had been settled, and the combined pressure of both Indians and settlers began to take its toll on the black bear population. The increased growth in human population and heavy logging hastened the bear's decline. Major sections of most mountain ridges were cleared of trees up to 4,000 feet. The effects of habitat loss and increased hunting with dogs forced the bears to live at higher elevations in areas less accessible to humans. By the 1920s the animal was essentially nonexistent at lower elevations in what was to become, in 1934, the Great Smoky Mountains National Park.

Although few bears remained by the 1930s, the records of several naturalists indicate that the animals responded immediately to the relative protection afforded by the creation of the park. One complication was that by the mid-1940s, the chestnut blight, which hit in the mid-1920s, had killed off most of the chestnut trees in the area. Thus, while the black bear population was being effectively protected from overhunting, its major food source (chestnuts) was disappearing from the mountain slopes. Now, after thirty years of protection, the vegetation has substantially recovered from the prepark logging operations, and the chestnut has been replaced by other tree species, primarily oak and hickory, which provide edible nuts for the black bears.

The Smokies are an excellent example of an area in which many of the various pressures of civilization impinge upon a supposedly protected bear population. More than eight million tourists pour into the Great Smoky Mountains National Park each year; a figure equal to the combined annual visitations to the Yosemite, Yellowstone, Grand Teton, and Rocky Mountain National Parks. The park's major attraction is vividly and symbolically displayed on the signs of many motels and businesses in the area and in the souvenirs sold in the numerous shops, including dishes, ashtrays, postcards, placemats, towels, ceramics, and wood carvings. We allude, of course, to the "Smoky Mountain Black Bear." There are few other places in the eastern United States where a vacationer can expect to see this large, free-roaming carnivore.

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park pop[illegible] animal[illegible] of the total [illegible] have little [illegible] tion the [illegible] [illegible] of [illegible] escape dete[illegible] the abundant [illegible] and dense understory vegetation.

We found that interesting differences in sex and age structure occur not only between the bold panhandling bears and the shy backcountry bears in the park but also between these park animals and hunted populations outside of the park. Males and younger animals in the park, for example, move and disperse farther than adult females, bringing them into greater contact with park visitors. Thus, the wider-ranging males and younger animals are more vulnerable to hunting outside the park.

An over-all age structure of nearly 70 percent adults (4.5 years or older) within the park, compared to 40 to 50 percent for the population outside of the park boundaries, indicates the influences of protection afforded by the park. The average age of adult park females is greater than that of adult males, another reflection of how the more restricted movements of the females decrease their vulnerability to human exploitation outside the park.

Our data on movements and reproduction of park bears indicate that at high densities there is considerable home range overlap of mature females and that a high proportion of females are barren. Some compensatory mechanism must have evolved to restrict productivity at dense population levels. At the present time we assume this to be a behavioral relationship based upon social intolerance, but we do not know to what

Cubs are agile climbers, often scooting up trees when alarmed. Mature bears also climb and may overwinter in tree trunk dens as high as 60 feet above ground.

Chuck Ternes

Chuck Ternes

Bears adeptly remove fruit with their lips from thorny branches. Raspberries are important in their diet, helping them recover from winter dormancy and providing sustenance until acorns and hickory nuts mature in the fall.

extent the lowered productivity may also be food related.

Population density is especially difficult to ascertain for the members of the order Carnivora, typically shy, secretive, and far-ranging mammals. Using several techniques, we have found that our study area (the southwest quarter of the park) supports a population of approximately one bear per square mile. Smaller land units deeper within the park, however, approach densities of two bears per square mile, a figure twice as high as previously reported. Factors contributing to higher densities and concomitant smaller home range sizes appear to be inaccessibility, which affords relative protection from poaching and free-ranging dogs; prime denning trees located in unlogged areas; maturing oak-hickory stands as sources of fall food; and a diversity and abundance of berry crops in the summer.

Summer is a period of food abundance for the black bear; increased feeding activities reach a peak from August to mid-September. Variations in temperature, shade, and moisture created by the diverse topography result in the ripening of various species of berries throughout the summer. The widespread availability of berry crops, which enables more bears to live in a given area, contributes to the small summer home ranges. Analysis of the contents of bear droppings reveals that blackberries, huckleberries, blueberries, wild cherries, and serviceberries make up a significant proportion of the black bear's summer diet. (Bears are remarkably adept at using their lips to feed on the small berries.) The lack of dependence on human (artificial) food is reflected in its low occurrence in their diet during peak visitor use of the park in July and August. This is true even for those bears that frequent campgrounds, trail shelters, and roadsides.

Mating occurs in summer. The fertilized egg divides only a few times and becomes a blastocyst, which floats freely in the female's uterus but does not attach itself to the uterine wall and begin further development until December. Delayed implantation seems to be an adaptation for preventing the developing pre- and postnatal young from making demands on the mother's metabolic reserves until after the dramatic weight gains associated with the nut and berry crops of late summer and autumn. If ample food is not available, cubs may not be produced at all.

Telemetry data reveal that travel movements are restricted during the summer period of food abundance—except for males in search of females in heat and for occasional young animals making exploratory probes into new habitat. Crepuscular activities are the rule and the use of beds during the day is common. These summer day-beds are typically small depressions created when large trees are

uprooted. High daytime temperatures and cooler nights probably contribute to this activity pattern, the bears taking advantage of cooler periods for foraging and perhaps breeding.

Mid-August brings the first ripening of acorns and hickory nuts (mast). Even while late summer berries are hanging from trees and shrubs, bears begin moving into oak-hickory stands. The death of the American chestnut has left acorns and hickory nuts as the bears' main alternative for a naturally occurring, nutritious source of fall food. But unlike chestnuts, oaks and hickories are unreliable sources of food because cold weather in late spring can reduce the fall production of nuts. Year-to-year availability of mast is therefore a major key to annual population fluctuations. But many other species of animals also feed on mast; the black bear must compete with turkey, white-tailed deer, ruffed grouse, gray squirrels, raccoons, and the European wild hog—the last, an exotic introduction that is capable of consuming large quantities of mast.

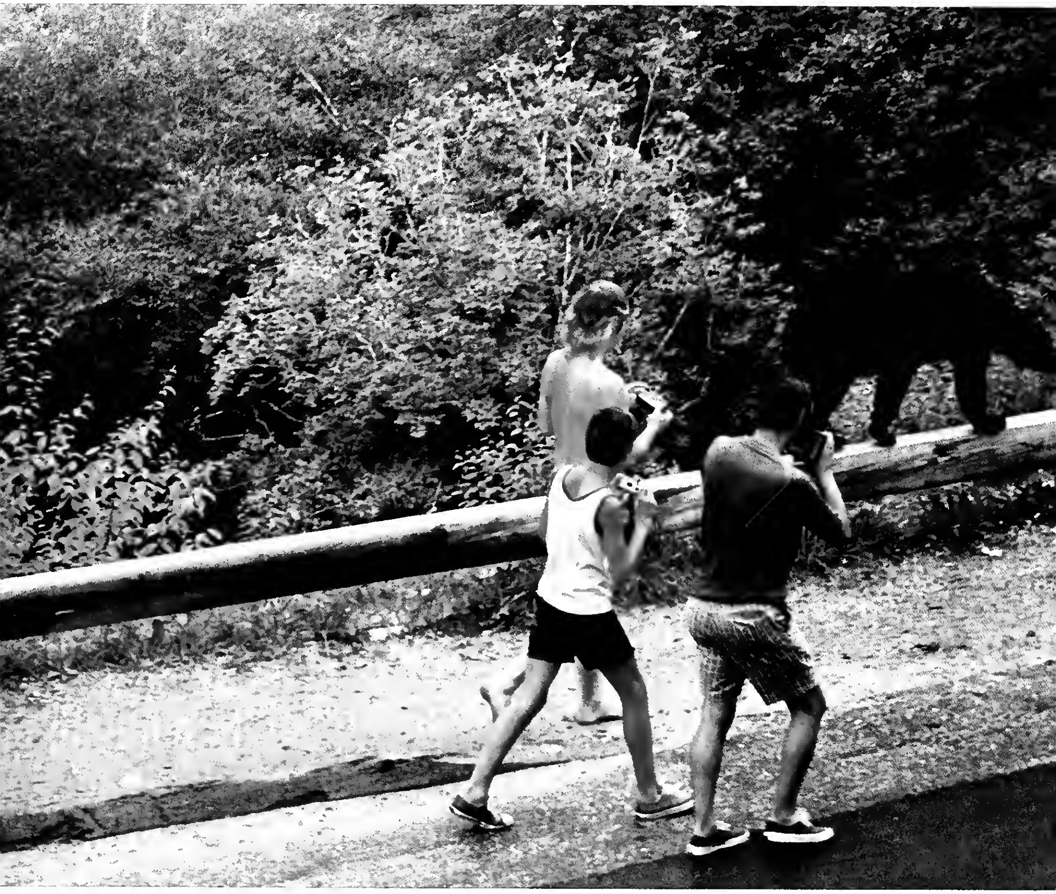
The black bear, however, puts its tree-climbing ability to efficient use and ascends even the tallest oaks to forage for acorns. Feeding may take place up in the tree or on limbs as large as three to four inches in diameter, which the black bear severs by clawing, twisting, and biting. Oak stands often give the appearance of having been devastated by a windstorm after black bears have fed in them, but such pruning has little detrimental effect on the trees. The black bear's ability to feed on acorns before they fall gives it a competitive advantage over other animals such as the wild hog.

During periods of food scarcity, in the fall, black bears, particularly males, may forage over long distances. The intensity and extent of such fall movements (the fall shuffle) is directly related to the scarcity of mast. A year of poor mast production results in more animals moving farther from their established summer ranges; thus the probability of being killed increases as the animals move into lower elevations, into peripheral areas of the park, and into unfamiliar private lands outside the park unoccupied by a resident bear population. The last is truly the land of no return for many black bears because of the toll taken by hunters.

Such periodic flushing of bears from the sanctuary of the park may have some beneficial effects if the poor mast years are not too severe or repeated too frequently. Males tend to make up a high percentage of those individuals moving outside the park. Since the black bear is polygynous, removal of excess males, particularly older ones, may do little harm to the population, and may even help it by removing the more socially intolerant

Candy, cookies, and other junk food from tourists are only marginal in bear diets, even among the 5 percent of the park's bears that panhandle. If the animals relied heavily on handouts, they would be malnourished.

Chuck Ternes



older animals. Also, it is the male panhandler that tends to be more aggressive and causes more problems in terms of property damage and injury. In 1969 and 1973, years following poor mast production, the number of bear incidents in the park decreased by 15-fold and 5-fold, respectively, from the previous years.

After the fall shuffle many of the foraging bears exhibit strong homing tendencies and return to their summer home ranges. The onset of denning begins in November and December as their movements diminish. Lack of droppings located during November indicates that feeding ceases.

The timing of denning is apparently associated with mast availability; for sufficient fat deposition to take place, bears must stay out longer during years of mast scarcity. Although we have detected occasional activity throughout the winter, most bears remain in their dens until March unless they are disturbed. They do not defecate, urinate, drink, or feed during this period, and the intestinal tract becomes blocked with a fecal plug until the bears emerge in the spring. This is a remarkable physiological feat, equivalent to adaptations of so-called true hibernators such as ground squirrels. In contrast to the slight decrease in the metabolism of bears, the metabolism of true hibernators decreases dramatically, but these animals may awake and defecate, urinate, or feed.

Most den sites in the park are not the traditionally recorded locations, such as the bases of hollow trees, under rock ledges, in rhododendron patches, or under overturned trees or stumps. In our study area most dens are cavities—formed by decay after the breakage of a large limb by lightning or high winds—30 to 60 feet above the ground in large oak, hemlock, or maple trees. This is not surprising in light of the bear's good climbing ability; also, its arboreal feeding activities for acorns and honey may contribute to the bear's ability to locate such sites.

These dens offer safer quarters for bears than ground-level dens because of the distance from humans and their activities. Often viewed by foresters as cull or overmature, the den trees

Alan Ternes

Recklessly trailing an adult bear in the hope of taking photographs, park visitors risk injury should the animal become aroused. If bears interact aggressively, they are trapped and removed to remote areas of the park.

are essentially relicts left from the prepark logging era. Even then they were classified as poor timber or were too inaccessible for loggers. In many areas of the East where the black bear has been forced into shrinking islands of habitat, the availability of such den trees could play an important role in population survival.

The dormant female bear gives birth during the last week in January through the first week of February. The number of cubs varies from the usual two to the rare four or five. Born naked with unopened eyes, they are about the size of a Norway rat and weigh about half a pound. Since an adult bear can reach 200, 400, and in the case of some males, more than 600 pounds, the ratio of birthweight to mature weight is larger than in most mammals. This high weight ratio is advantageous to a nursing female since she and the cubs must subsist off her fat stores until spring.

On emerging from their dens in March and April, black bears find themselves faced with very limited food sources. During this period, the bears must subsist on remaining stores of fat and early emerging herbaceous vegetation. Various grasses along trails are grazed; the extremely loose consistency of droppings composed entirely of grasses in early spring suggests that the possible laxative properties of this food may aid in the removal of the fecal plug. Our food preference studies indicate that grass is an unfavored food throughout the year and may be eaten in spring only because little else is available.

The parasitic squaw root plant (*Conopholis americana*), which is very succulent in its early stages of growth, is a commonly eaten and highly favored food during the spring. Limited feeding activity continues until berries begin to ripen in early June; the bears lose weight until this time. The condition of the species in late spring and early summer is thus related to the success of the previous year's mast crop. The abundant and diverse berry crops of summer allow the population to recover from the lack of feeding in winter and scarce foods of spring.

Summer brings an annual upsurge of visitors to Great Smoky Mountains National Park. Whether it is the desire to see or interact with this animal in its native habitat or simply to visit and linger awhile in an area where the species occurs, the attraction is there. Few visitors stop to think of the artificial situation their sheer numbers create. No matter how bearproof the garbage cans or how efficient the sanitation procedures, large numbers of people mean coolers, picnic baskets, and backpacks loaded with items that are attractive to bears. Handouts or picnic scraps are enough reinforcement to set into motion a series of human–bear interactions that become more intense as the summer progresses.

The temptation on the part of the visitor to keep the "cute" animal within viewing range is great, and food is used to entice the bears to remain for picture taking or viewing. The National Park Service is then faced with the problem of maintaining the fine line between a high rate of return in the form of visitor satis-

faction, on the one hand, and visitor injury or property damage on the other. Fortunately, unlike the grizzly, the black bear is far less aggressive and conflicts with humans are typically only food related and not as serious in terms of injuries.

One theory to explain the differences in aggressive behavior between these two closely related bear species proposes that grizzlies evolved in a relatively open habitat so that the female had to "stand and defend" her cubs, perhaps from adult males or other predators. Black bears, in contrast, had the ready access of thick understory vegetation and large trees as an escape mechanism. In this context it is interesting to note that young and adult black bears climb trees whereas only young grizzly cubs exhibit this ability.

For some visitors the end result of human–bear interactions is unpleasant; for the more aggressive bears, it means their removal to remote areas of the park. The transplanting of bears offers only a partial solution to the problem, however, since they exhibit strong homing tendencies; about 50 percent of transplanted bears have returned from the farthest reaches of the park to their original home ranges.

How far should the National Park Service go in attempting to decrease the frequency of interactions leading to injury or property damage? What are the proper steps to take in balancing visitor satisfaction against the survival requirements of the bears? In searching for solutions, suggestions have been made for the use of aversive stimuli to repel bears, for the creation of feeding areas, the removal of all artificial sources of food, better dispersal and control of visitors, strict enforcement of regulations regarding the feeding of bears, and more innovative educational programs for visitors. We feel that many of these ideas offer worthwhile areas for future research efforts; visitor knowledge and attitudes are particularly important areas to explore. For example, a survey of persons who were injured or sustained property damage by black bears indicated that the respondents were almost unanimous in blaming themselves and not the bear for the unpleasantries. Many rejected suggestions that bears be removed from the park as a solution to human–bear interactions. This is important because many managers of areas containing potentially dangerous wild animals (for example, bears, rattlesnakes, and so on) are almost pathological in their fear of such incidents and often seem willing to engage in policies that, in effect, sign the death warrant for the animal population in an effort to reduce a low risk to zero.

For the bears, the more serious human–bear interactions in the park and around its periphery occur with poachers. Many more individual bears are involved, and the potential for detrimental effects on the bear population is very significant. Hunting traditions established before the creation of the park persist, and poaching is still quite prevalent. The exact effects on the bear population are unknown, although significant numbers of bears are lost in years of poor mast production.

Other reasons for continued illegal hunting include spite of the local poachers against the National Park Service as a federal agency controlling the land; procuring meat, hides, or cubs; contract hunts with clients willing to pay the price; peer status among local hunters; and simple boredom.

In the eastern states the unknown losses due to illegal hunting make it especially difficult for state game and fish agencies to establish biologically sound hunting regulations. This is important since bears have evolved a reproductive strategy involving small litter size, delayed sexual maturity, and a long life-span in an ecologically stable habitat. Before man came on the scene, bears had virtually no natural enemies and thus developed no mechanisms to adjust quickly to conditions causing heavy mortality. This contrasts with the European wild hog in the park, which is sexually mature in less than a year and may have two litters of 4 to 6 young a year. The margin of error for bears is very small; poaching, plus other unknown mortality, can easily extirpate bears in local areas.

Declining harvests of bears have occurred in many states of the eastern United States. The disappearance of large, protected, relatively uninhabited tracts of land in the East is a primary reason for the decline of the black bear from its precolonial population levels. As the burgeoning human population spreads into more esthetically appealing areas—which are often juxtaposed near state and national parks, forests, and refuges—it forces existing populations of bears into smaller and smaller land units. The increased density of people leads inevitably to an increase in the incidence of interactions; to human usurpation of the bears' feeding and denning areas and to an increased number of bears killed by farmers because of depredations (raiding farms, killing stock, or stealing honey) and by poachers.

Relatively large tracts of land still exist in the eastern United States from which black bears have been extirpated; many of these areas could probably sustain a population if systematic reintroductions were attempted. More intensive efforts are needed by ethologists and wildlife ecologists to study the behavioral and ecological ramifications of animal populations being confined to such enclaves, especially for a species that is particularly sensitive to the intrusions of man.

In a world in which the ranges of many species of wildlife are shrinking into such decreasing islands of habitat, we need to look more closely at the ways in which species adapt or succumb. Some species can and will adapt if we apply in advance the appropriate ethological and ecological principles that are keys to their survival. But humans will be the final arbiter of most of our wildlife species; we hope the islands of habitat will not dwindle into only zoological park enclosures and that the black bear will not be just a symbol of the wilderness of the eastern United States, but forever a reality. □

Black bears are the number one tourist attraction of Great Smoky Mountains National Park. Their popularity becomes a paradox, however, when attempts by park managers to prevent occasional incidents with humans are made at the bears' expense.

Alan Ternes


10

Human Locomotion

by Adrienne Zihlman and Douglas Cramer

Evolutionary modifications in our musculature and skeletal system help distinguish us from our apelike ancestors

The stride of the Olympic runner, the pinpoint accuracy of the baseball pitcher, the mother at the supermarket carrying her baby on one arm and a bag of groceries on the other, all illustrate the unique locomotor adaptation that makes us peculiarly "human." Increased brain size was originally regarded as the earliest human characteristic. But two million years ago, early hominids—using stone tools and possessing brains not much larger than those of the apes—already had modifications of the pelvis, legs, and feet that prove them bipedal. Walking on two legs—the first step away from the apes—freed the arms and hands for carrying, for tool use, and for skillful movements. The consequent elaboration of hand–eye coordination and more complex thinking ultimately resulted in our brain development.

Walking, running, throwing, carrying—these activities seem very natural to us, but they require an extremely complex set of interactions between the nervous, muscular, and skeletal systems. Two limbs must accomplish in humans the motor functions performed by four in our quadrupedal ancestor, a creature that was probably much like a chimpanzee. A problem that had to be coped with in the transition from quadrupedalism to bipedalism was that of balance, especially at the fleeting moment when one foot must support the entire body. Because of this precarious balance, it is easier for humans to walk fast than to walk slowly.

The human system of locomotion combines forward and rotational movements about the trunk and hip, knee and ankle joints. To take a step in walking, the heel is put down first, the hip and knee begin to straighten out, and the full weight is shifted to that foot, with the pelvis and trunk maintaining a stable upright position. The other leg then swings forward, the hip joint rotating about the weight-bearing leg. At this instant one foot supports the entire body. The result is a smooth forward motion—easy enough for healthy individuals, but difficult for those with an injury or a disease such as arthritis.

Balance and motor coordination are processes that develop during the earliest years of life. Young children first learning to walk appear awkward. Their feet are spread wide apart to compensate for their short legs and underdeveloped lumbar curve; their arms are outstretched to assist in balance. They cannot maintain equilibrium or make smooth forward motions involving rotation of the body around the stable limb. Once these skills are mastered, it is possible to keep the feet closer together and to take longer strides. The arms become less important for maintaining balance and tend to swing to counter rotation at the hips.

The breakdown of this pattern can be a sign of aging. In old age, coordination deteriorates, the bones become brittle, and the hip muscles weaken; hence the legs rotate externally at the hip and the toes point outward. Because of the weakening of the hip muscles, the ability to rotate the trunk over the hip for purposes of balance decreases. To compensate, old people take short steps and place their feet far apart in a walking pattern resembling that of small children.

To accommodate increased stresses and forces resulting from two-legged locomotion, larger hip, knee, ankle, sacroiliac, and lumbosacral joints evolved. Some side effects of this adaptation have been the high incidence of arthritis, common fracture of

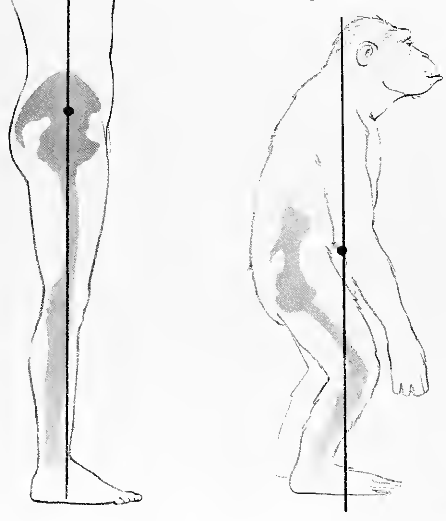
Human skeletal structure in the pelvic area makes possible the rotational movements crucial in such sports as football.

UPI and Douglas Cramer

the bones forming these joints, and the universal complaint of low back pain.

Muscles are essential for movement; they also support joints and act as shock absorbers. The shape of pelvic, leg, and foot bones reflects the muscles that attach to them and the forces the muscles generate. Human muscles create a configuration of body curves unlike those of any other animal. A striking example is our rounded buttock, formed by the gluteus maximus, our largest muscle. This muscle serves several functions: it straightens the hip joint and absorbs stresses from it, supports the sacroiliac joint, and assists in stabilizing the trunk over the leg and foot. It is most active during vigorous motion involving a shift of weight, such as rising from a sitting position or going up a slope. The gluteus was named "maximus" because of its large size in our species; in other animals, the equivalent muscle is relatively small and unimportant and is accordingly called "superficialis."

Beneath the gluteus maximus are two muscles—the gluteus medius and gluteus minimus—responsible for rotation and stabilization at the hip joint and consequently for maintaining balance. These muscles contribute to the roundness of the hips. They contract with each step and keep the pelvis and trunk over the foot. Without this stabilizing action, one would fall to the unsupported side of the swinging leg. When these muscles are injured, the trunk is thrown from side to side with each step, noticeably affecting the smoothness of a normal gait.



The center of gravity in humans is in the pelvis, and the line of gravity through the body aligns the hip, knee, and ankle joints, facilitating standing in an upright position and two-legged walking. The center and line of gravity in chimpanzees, by contrast, favors tree climbing and quadrupedal knuckle walking.

Douglas Cramer

Another human body curve is that at the front of the thigh, which is full and rounded. The fullness comes from the large, powerful quadriceps muscle—made up of four parts—which straightens the knee joint. This muscle, a powerful propulsive force when going uphill, also acts as a brake when walking down a steep incline.

The rounded, well-defined calf muscles, which narrow into the long Achilles tendon at the ankle, are also distinctively curved. When these muscles contract, the ankle extends, thereby assisting in forward propulsion. The foot pushes against the ground, the movement passes over the toes, and at the last phase before pushing off, the great toe bears most of the body's weight. Anyone who has ever injured a big toe appreciates how important that digit is in walking.

Many of our bodily structures—the ankle, the knee, the pelvis, and the back—represent evolutionary compromises between conflicting functions. The ankle joint, a composite of three smaller joints, represents a compromise between stability and flexibility. Its primary movement is extension and flexion in a single plane, as in level walking. Ankle rotation, although consisting of only a few degrees—much less than in primates—is essential for fine adjustments and increases when walking on uneven, rocky, or sandy terrain. This compromise between stability and flexibility enables us to maneuver on surfaces ranging from level sidewalks to ski slopes—but it also results in a lot of sprained ankles.

The knee joint represents a similar compromise. The strong ligaments and the bony congruence of the joint surfaces provide stability when standing and walking, but they also allow for a few degrees of rotation that are crucial for adjustments during walking, throwing, running, or sitting on one's heels. Our knees support us when we stand or walk or run long distances—actions that involve little rotational movement—but our minimal knee rotation makes us poor climbers. In contrast, our primate relatives can rotate their knee joints a great deal. This ability is probably functional for keeping the knees out to the side when climbing or walking along the tops of branches, although it may make primate knees too mobile

for supporting weight in bipedal walking or running.

The compromise in the human knee between stability and flexibility is well illustrated in sports. The flexibility of our knees makes most athletics possible, but the price often is severe knee injuries. Most of these, particularly those incurred in playing basketball and football, result from violent pivoting of the body while the foot is firmly planted—a movement that twists the knee and tears the supporting ligaments that provide its stability.

The most central and complex structural compromise is the human pelvis. Unlike that of four-footed animals, the human pelvis bears the weight of the upper body and supports the contents of the abdomen. In monkeys, the tail muscles are the equivalent of the muscles that support our guts. The human pelvis also contains the hip joints and the muscles that control them, and in females, as in all vertebrates of that gender, the pelvis has a bony ring large enough to permit birth. The large human brain requires a large birth canal, but a wide pelvis is less efficient for bipedal locomotion than a narrow one because it increases the side-to-side "rolling" component. Preadolescent girls can run as fast as boys, but at puberty their pelvises expand more than those of males; consequently, their speed drops off considerably. Endurance, however, remains.

The human back is a common source of medical trouble and pain, particularly the lower, or lumbar, region. This flexible area accommodates the twisting and turning motions of locomotion, but it is also stable, with large joint surfaces and ligaments to bear the stresses generated by body weight and motion. The back's flexibility is essential for most activities involving the upper body, for example, throwing. But if the back muscles are not in tone or if an abnormality exists, such as asymmetry of a leg or of the upper body, back alignment can be thrown off, resulting in pinched nerves and consequent pain. Gravitational forces also contribute to such ailments as slipped disks, hernias, and varicose veins.

Despite the liabilities that result from our locomotor system, its advantages are far-reaching. In thinking about our bipedal adaptation, locomotion should be viewed as a whole-body activity that involves a complex set of interrelated behaviors, including carrying and throwing, rather than simply as a way of moving from one place to another. Our kind of two-legged locomotion allows a wide variety of motor patterns: it is a "doing" system. For example, no other primate can throw with precision, or walk long distances while carrying objects in its arms and hands.

In contrast, the joints of monkeys and apes are adapted for mobility and tree climbing, rather than for endurance and stability on long overland trips. Ungulates, such as horses and antelopes, on the other hand, travel

Propulsive action in most animals is by hip extension and knee flexion; the latter, as in this dog, is opposite to that of humans.

Douglas Cramer

very effectively over long distances on the ground, but their joints move primarily in one plane—through flexion and extension—so that, with the exception of an occasional hungry goat, you don't find ungulates in trees.

Numerous animals other than humans have moved around on two legs: birds and kangaroos, among living species; some dinosaurs, from the fossil record. Their spines, however, remain horizontal or have a slight upward tilt, and they usually have heavy tails, for balance. Human two-leggedness is different: the combination of the vertical spine and the pelvis have freed our forelimbs for tool making, throwing, and digging—nonlocomotor activities that constitute the essential basis of the adaptation and success of our species.

Chimpanzees, our closest living relatives, are of particular interest because they are probably similar to the population that gave rise to our ancestor, the primate *Australopithecus*. Primarily adapted for climbing trees and quadrupedal knuckle walking, chimpanzees can, and on occasion do, walk and stand erect. But their bipedalism is both behaviorally and structurally different from that of *Homo sapiens*. They go only short distances on two legs and stand upright for only a few moments, and both of these actions appear infrequently in their total behavior pattern. Their short legs and long, massive arms and trunk give them a higher center of gravity than ours, and hence a more precarious balance when upright. When they stand, chimpanzees do not completely straighten their hips and knees; instead they assume a kind of Z shape, which requires more muscular activity to maintain and induces fatigue more quickly than does our straight-jointed, vertical posture. Humans require only ligaments, not muscles, for standing upright because the line of gravity passes through the joints.

Chimpanzees have no muscles for hip rotation when upright; when they walk erect, their feet are wide apart, the trunk sways from side to side, and the lower back is rigid. This structural set impairs both their walking and throwing ability. Chimpanzees can throw overhand, but because their lumbar region is immobile, they cannot position themselves or follow through by rotating the body around the hip as humans do. A chimpanzee's throw consequently lacks the power and precision characteristic of human throwing.

Chimpanzees possess a variety of muscular abilities—standing, walking, throwing bipedally—and a complex communication system, in addition to their capacity for tool using and killing and eating animals for meat. Although they perform some of these activities relatively infrequently, natural selection favored and expanded this entire range of motor behaviors in the part of the ancestral population that diverged and began the hominid line.

The two- to five-million-year-old fossils unearthed in East and South Africa, and accepted as early human remains, were found with stone tools, and their pelvic and limb bones suggest that the hominids were bipedal. The australopithecine fossils consist mostly of jawbones, teeth, and a few skulls; less than 10 percent are pelvic or limb bones. Although much emphasis has been placed on skulls and teeth, the pelvis is where the action is. Even before stone tools show up in the fossil record—in the lower Pleistocene Epoch, more than 2,000,000 years ago—the australopithecine pelvis had probably diverged from that of our earlier ape ancestors. Prior to the discovery of a fossil pelvis in Ethiopia in 1974, the first such find in East Africa, australopithecine pelvises were found only in South Africa. The half dozen or so that exist in museums are much like the modern human pelvis, but with smaller hip joints. Australopithecine legs were probably not as long as ours and the arms were probably longer in proportion to the body. It is likely that australopithecines did not walk exactly as we do, but their bipedal adaptation was eminently successful. They are thought to have inhabited the savannas of East and South Africa for a period of one to two million years; later they gave rise to *Homo erectus*, who existed throughout the Old World by 500,000 years ago.

The multi-million-year-old crude stone tools dug up with *Australopithecus* in Lake Rudolf, Omo, and Olduvai Gorge in East Africa, testify to the primate's bipedal adaptation with freed hands. These artifacts were probably used mainly to obtain food and, perhaps, for self-protection. *Australopithecus* was in all likelihood primarily a forager-gatherer of plant food, which grew widely over the open savanna. The animal's adaptive complex included the ability to walk erect, to carry gathered plant food, water, and small animals that had been caught and killed, as well as such defensive objects as rocks and sticks. The distances between the sources of food, water, raw material for tools, and suitable campsites were often great, and various terrains—sandy, hilly, rocky, muddy, and perhaps, marshy—had to be negotiated. *Australopithecus* used areas around lakes and rivers for camping and shelter but most of its food came from open country. The relationship between the evolution of erect posture, evolution for efficiently covering long distances, and evolution for throwing and carrying were thus all interrelated in *Australopithecus*.

The australopithecine brain was only a little larger than that of chimpanzees, although its internal structure may have been reorganized as a result of tool use and bipedalism. There is some evidence of an increase in the size of the cerebellum, the coordination center for the equilibrium that is basic to bipedalism, as well as to the hand–eye movements required for using tools.

The manner in which the human locomotor system has evolved favors walking and carrying over standing and sitting. We find it more fatiguing to stand than to walk. Active leg muscles aid circulation by pumping blood upward to the heart, vigorous sports keep muscles and joints from becoming weak and slack. Thus, when we see a football player running or dodging tacklers or snaking swivel-hipped through the opposition or throwing an accurate fifty-yard pass, we are watching the result of several million years of an evolving motor pattern. □

The manner in which our musculature has developed is one of the adaptations that makes humans human.

UPI and Douglas Cramer


Cramer

The Importance of Being Feverish

by Matthew J. Kluger

An elevated temperature may be a sign of illness; it may also be a part of the cure

Most people associate a fever with the harmful effects of infection. In fact, pharmaceutical advertisements often give the impression that a fever is the cause of an illness, rather than a symptom, and that suppression of the fever is an effective treatment of the underlying infection. We are told to treat fevers with antipyretics, drugs designed to return our body temperature to normal, a treatment that has been an accepted part of medical practice at least since the ancient Romans began deriving aspirinlike salicylic acid from the bark of willow trees. That this body response, which has evolved over millions of years, might in fact be beneficial in killing infecting microorganisms is rarely implied in such advertisements.

The study of fever has always figured in medical history. Some 2,400 years ago Hippocrates, who is considered one of the founders of Western medicine, attempted to explain the causes of the mysterious fever—malaria—raging through his country. Noting the correlation between local climatic conditions and initiation of the attacks of fever, he concluded that the weather was the cause of malaria (hence its name, which means "bad air"). His interpretation was erroneous, but based on the information available to him, this was a sound epidemiological approach.

Not only have physicians studied fever, they have also attempted to treat it with a wide assortment of remedies. Andromachos, the physician to Emperor Nero, proposed an instant fever cure-all made from more than sixty ingredients. His remedy was perhaps mild compared to others, which included fleas and the eyes of crabs, wolves, and snakes.

Not all physicians, however, advocated the abolition of fevers. Rufus of Ephesus, an anatomist-physiologist working in the first and second centuries A.D., believed that many nonfebrile diseases, such as epilepsy, convulsions, and asthma, could be remedied by inducing a fever. This approach, subsequently called "fever therapy," is still a part of medical practice and has been used with varying degrees of success as a treatment for syphilis, gonorrhea, and some forms of cancer. Thus, medical practice, although most often attempting to suppress fever, does include two apparently opposed attitudes toward the phenomenon.

Our present understanding of the causes of fever was made possible only in relatively recent times. Not until the invention of the thermometer by Galileo Galilei in the late 1500s was it even possible to determine normal and febrile body temperatures. While the technology for the development of the thermometer, including primitive thermometers, had existed at least since the days of Hero of Alexandria in the first century B.C., it took the creative genius of Galileo to rediscover and appreciate this useful tool. Within a few years of Galileo's discovery, Sanctorius, his colleague at the University of Padua, used a crude thermometer that was sensitive not only to changes in temperature but to barometric pressure as well (technically a "barothermograph") to measure the "heat of persons in a fever." The use of temperature measurement as a diagnostic tool was thus initiated. But not until the development of the microscope by Galileo in the early seventeenth century, its subsequent refinement by Antony van Leeuwenhoek, and the later development of the germ theory of disease (largely the work of Louis Pasteur in the late nineteenth century) were scientists able to link the role of microorganisms with the onset of a fever. (Some fevers, of course, develop from noninfectious diseases, cancer for example, or from other causes such as severe allergy or injury, but our primary concern here is with fevers brought on by infection.)

While our knowledge concerning the course of fever has improved over the last 2,400 years, we are still trying to determine its actual cause. By what mechanism do so many different pathogenic organisms all produce a similar febrile response? There are no definite answers, but our understanding is growing.

The primary area in our brain that receives information concerning temperature—both from the outside world and from deep body areas—is the hypothalamus. The hypothalamus serves as an area for the integration of all thermal information and also acts as a thermostat, regulating our body temperature at some prescribed level. When we are exposed to temperatures that are too high, the hypothalamus sends signals to our sweat glands to increase the output of sweat. (The heat required to evaporate sweat lowers the body temperature.) The hypothalamus also signals our metabolic machinery to lower our production of internal heat. Presumably through reflex pathways leading

The desert iguana, like all cold-blooded animals, regulates its body temperature by moving to cool or warm spots accordingly. This makes it a good subject for the study of fever—when infected, will the lizard try to cool itself or keep its temperature high?

I.P.L. Fogden, Bruce Coleman, Inc.

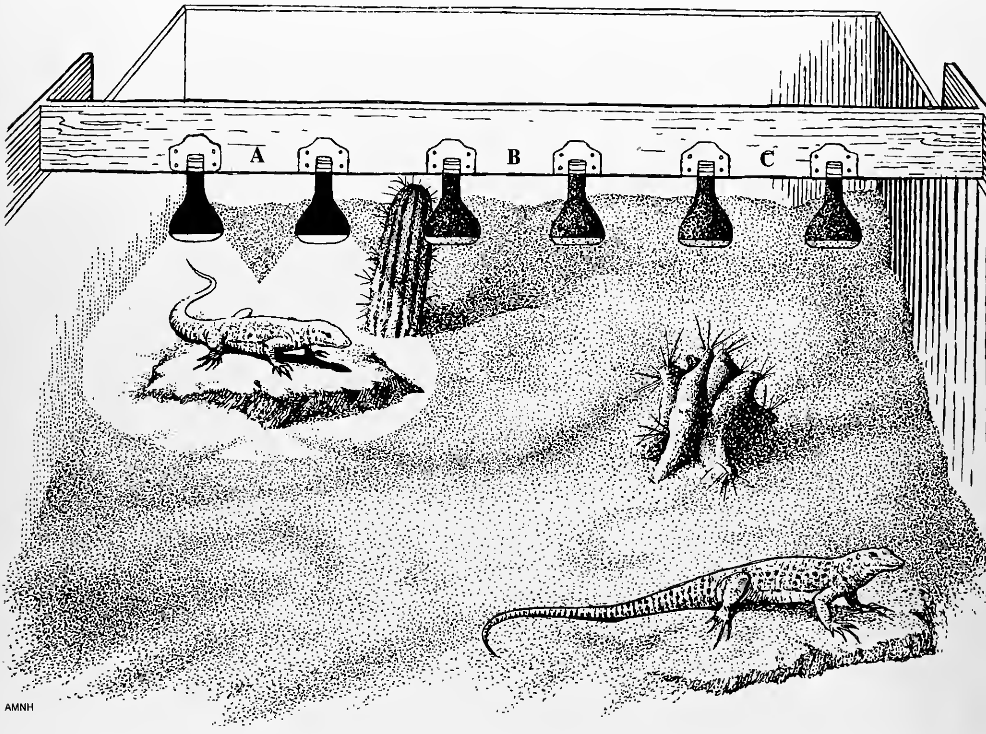
from the hypothalamus, we become conscious of the heat and we move to a cooler area. We also drink cold fluids, although this is a somewhat inefficient heat-loss mechanism.

Conversely, when we are exposed to the cold, information integrated in the hypothalamus leads to a cessation of sweating, an increase in metabolic heat production (shivering), and the conscious selection of a warmer area and warmer food and drink. Thus, the signals from the hypothalamus initiate both physiological and behavioral responses for body temperature regulation.

Fever begins with the presence of a foreign substance, say bacteria, in our tissues, which activates our leukocytes (white blood cells) to engulf or phagocytize the invaders. The bacteria needn't be alive since our leukocytes respond only to the cell walls of the bacteria, which contain the so-called endotoxin. In the process of ingesting the bacteria, the white blood cells produce a small protein called endogenous pyrogen. This pyrogenic, or fever-producing, material circulates throughout the body; some of it presumably enters the brain, where it causes an elevation of the hypothalamic thermostat.

Recently, scientists have speculated that endogenous pyrogen increases the production of special substances called prostaglandins; these in turn cause the hypothalamic set-point to rise. In any event, in response to the elevation in the hypothalamic thermostat, an animal—behaving as if it were exposed to the cold—elevates its body temperature and, as a result of subsequent thermoregulatory adjustments, develops a fever. Although antipyretics such as aspirin do not affect normal body temperature, they do lower the temperature during fever; the latest evidence indicates that antipyretics may reduce prostaglandin levels, which in turn return the hypothalamic thermostat to its normal setting.

Before exploring the phenomenon of fever, it is useful to distinguish between fever, a response to harmful bacteria, and hyperthermia, a response to exercise or heat exposure. Like a furnace whose thermostat is raised and which then works harder to produce more heat, during fever we act as if our hypothalamic thermostat is set at a higher level. Consequently, we actively drive our body temperature upward by both physiological means (such as shivering) and



To study how lizards respond to infection, the author simulated a desert environment. The range in room temperature paralleled that of the desert—from about 55° at night to 85° during the day. Heat lamps that warmed the area beneath them to 120° were operated on a schedule: Those labeled A were on from 6:00 A.M. to 10:00 A.M.; B from 9:00 A.M. to 3:00 P.M; and C from 10:00 A.M. to 6:00 P.M. Thus, during the daytime lizards could select an ambient temperature of from 85° to 120°. Following infection with live bacteria, the lizard on the left stayed near the lamp, thereby elevating its temperature to a feverish level. The uninfected lizard, foreground, shifted in the box so that its body temperature remained between 104.4° and 102.2°, normal for this animal. Kept in a warm environment, infected lizards survive far better than those maintained at lower temperatures.

behavioral mechanisms (perhaps wrapping ourselves with warm blankets and drinking hot tea).

In hyperthermia, however, the thermostat remains set at the same level, but the on/off switch fails. Consequently, the furnace overheats or, in this case, the body temperature elevates. Once we stop exercising or retreat from a hot environment, our body temperature returns to normal.

Although Hippocrates was speculating about the causes of fever more than two thousand years ago, even today we do not know whether it is beneficial or harmful to the organism suffering it. Some people have argued that the positive effect of fever therapy is evidence that fever itself is beneficial. In a patient undergoing fever therapy, however, the elevation in body temperature is both artificially induced and of greater height than that encountered during the normal course of an illness. Under normal conditions, the elevated body temperature does not directly destroy the infecting microorganisms. So the evidence from fever therapy clearly does not answer the question of fever's function during a normal infection, and we continue to be haunted by the following questions: Would a response such as fever, which is considered a universal response of warm-blooded animals, not serve some useful function? If fever were harmful to the host, would not selective pressures have led to its extinction?

To investigate the role of fever in disease, one could simply inject a population of animals with a suitable bacterium and allow half of the animals to develop the normal fever, while preventing the other half from developing the fever. The survival of the two populations could then be compared. If fever were beneficial, the population that developed the fever would have fewer deaths. Conversely, if it were harmful, the group that was prevented from developing a fever would have fewer deaths.

One difficulty presents itself, however. How could we prevent a fever from developing in a group of mammals exposed to a bacterial infection? The most obvious way is to simultaneously administer an antipyretic drug such as aspirin. Unfortunately, such an experiment would not give a definitive answer to the question. Since aspirin has numerous side effects, interpretation of any experiments using the drug would be difficult. Would any difference in mortal-

ity be due to the difference in body temperature, to the direct effects of the drug used to prevent the fever, or perhaps to a combination of both?

An alternate experimental design would entail manipulating the environmental temperature in such a way that one infected group was exposed to a comfortable environment and developed a normal fever, while the other was exposed to a cool environment that prevented the elevation of body temperature to the febrile level. Would this experiment be easier to interpret? I think not. In response to the cold, mammals initiate responses designed to prevent a fall in body temperature. Even if there were differences in the body temperatures of the two populations, there would undoubtedly also be differences in the amount of stress imposed on each group. The population exposed to the cold, for example, would have elevations in the levels of hormones partially responsible for the maintenance of normal body temperature.

What about cold-blooded organisms—the fishes, amphibians, and reptiles? To speak of fever in this group seems like a contradiction in terms. While birds and mammals (the so-called warm-blooded vertebrates) regulate their body temperature as a result of both physiological and behavioral adjustments, the reptiles, amphibians, and fishes regulate their body temperatures largely by behavioral adjustments. A turtle sitting on a log in the middle of a pond and a frog on a lily pad are familiar examples of cold-blooded animals raising their temperature by absorbing thermal radiation from the sun.

Over the past dozen or so years, laboratory investigations have shown that hypothalamic integration and control over the thermal responses of vertebrates, ranging from fishes to mammals, are similar. The primary difference between the cold-blooded (ectothermic) and warm-blooded (endothermic) vertebrates is the manner in which they regulate body temperature. Of the endothermic vertebrates, we also know that many, including birds, respond to infection with a fever.

What about the ectotherms? If they could develop a fever in response to a bacterial infection, we could design a definitive experiment that would answer the question of the function of fever. An ectotherm such as a lizard offers certain advantages for the experimental study of fever. In a natural setting, where there are large temperature differences from one microclimate to another (say from the shaded ground beneath a fern to a flat, exposed rock), a lizard can regulate its body temperature to within a narrow region. In a laboratory setting where the environmental temperature is relatively constant, the lizard's body temperature will remain at room temperature; thus, its body temperature can be easily maintained at any temperature by simply placing it in a chamber controlled at that temperature. This would enable us to inject populations of lizards with bacteria and study the role of temperature on their survival without the lizards attempting to alter their body temperatures physiologically.

We chose as our experimental animal the desert iguana *Dipsosaurus dorsalis*, a moderate-sized lizard about six inches long (excluding the tail) that adapts readily to laboratory conditions. The lizards were placed in a simulated desert environment, where the night temperature was a cold 55°F. and the daytime temperature ranged from 85° to more than 122°, depending on the location. Within this range the lizards were able to select their preferred temperature during the daytime. Using special thermometers placed in each lizard's rectum, we recorded their body temperature and found they selected a body temperature of about 100.4° to 102.2°.

Following infection with live *Aeromonas hydrophila*, a bacterium that causes red-leg infection in amphibians and reptiles, the lizards' body temperatures rose to between 104.0° and 107.6°. The lizards achieved this elevated body temperature only by selecting a site with a higher temperature a larger proportion of the time, not by increasing internal production of heat, as is largely the case with mammals.

We were now ready to test whether lizards infected with this bacterium and then placed in different constant environmental temperatures (that is, maintained at different body temperatures) would have different survival rates. Groups of infected lizards were placed in five different constant temperature chambers: at 93.2° and 96.8°, which correspond to low temperatures but are well within the lizards' normal range of exposure; at 100.4°, which is the normal body temperature of these animals; and finally at 104.0° and 107.6°, which correspond to low and moderate fevers, respectively.

The results were striking. At the end of three days at these temperatures, 96 percent of the lizards maintained at a febrile temperature of 107.6° were alive, whereas at the afebrile temperature of 100.4°, only 34 percent were alive. At 93.2° less than 10 percent survived. We later learned that the increased ability of lizards to survive at the elevated temperatures was due, not to differences in the growth patterns of the bacteria, but to some as yet unidentified increase in the lizards' defense mechanisms against the infecting bacteria.

Can these results be extrapolated to mammals? If specific aspects of the febrile response in birds and mammals could be shown to be similar, this would suggest a common origin of fever in these two groups. Mammals and birds evolved from primitive reptiles, so if mammalian fever originated in premammalian vertebrates (and did not evolve independently at a later time), then the function of fever might be similar in reptiles, birds, and mammals.

Hoping to increase our understanding of the evolution of fever, and perhaps its adaptive role, we decided to compare the febrile responses among the terrestrial vertebrates (reptiles, birds, and mammals).

In order to strengthen the case for a common origin of fever, we listed those characteristics of mammalian fever we felt should be found in the avian and reptilian classes. First, the reptile or bird should respond to an infection of live bacteria by developing a fever. Second, since the cell wall of the bacteria, not the live bacteria, contains the endotoxin that induces our own leukocytes to produce the fever-producing material (endogenous pyrogen), the reptile or bird should respond to an injection of dead bacteria by developing a fever. Third, antipyretic drugs should result in an attenuation of the fever. Lastly, in response to a bacterial infection, the reptiles or birds should produce endogenous pyrogen.

Our case was strengthened by our findings—all three classes of vertebrates developed a fever in response to live and dead bacteria, and the fever was attenuated by an antipyretic drug, thus satisfying the first three criteria. Still unresolved is the question of the development of endogenous pyrogen in reptiles and birds; investigations on this subject are under way.

Based on the similarities of reptilian, avian, and mammalian fever, I believe that the mechanism responsible for the development of a fever in response to infection has existed for several hundred million years. I also believe that fever evolved as a mechanism to aid the host organism in surviving the attack of the infecting microorganisms. But how the elevation of body temperature leads to this enhanced body defense is completely unknown. Possibly, although there is no definitive laboratory evidence for this, several components of the defense mechanisms, including the phagocytic activity of the leukocytes or their ability to be rapidly mobilized are dependent on temperature. Perhaps, as has recently been suggested by Eugene Weinberg of Indiana University, a fever is beneficial because it leads to a reduction of trace metals, most notably iron, that are necessary for the growth of microorganisms, a phenomenon called "nutritional immunity." Future investigations in this area might show that our body has evolved a relatively simple, yet ingenious, system for fighting infection—the removal of some trace element that is critical for the growth of the pathogen. Ecologists have long been familiar with this phenomenon in terms of the requirements for the successful establishment of a species in an area and the role of "limiting factors" in the environment. In the case of long-term infection, however, or of poorly nourished individuals, this phenomenon can also lead to anemia and impaired functioning of the defense system.

In tracing the role of fever in disease, I believe that the comparative approach to fundamental biological questions, relying heavily on evolutionary biology, can lead us to answers we would not otherwise obtain.

Among the still unanswered questions are, What groups of mammals develop fever? How would a mammal that is capable of hibernating, such as a bat or a ground squirrel, respond to an infection? Can a fever be induced in an amphibian? a fish? If our speculation that fever is beneficial in mammals is correct, what causes the clearly dangerous high fevers that are occasionally encountered? Might fever be of positive value in some species and vestigial in others? By continuing to employ comparative techniques, we stand at the real beginning of a study first attempted 2,400 years ago. □

The Fencing of America

Increasing pressure from crowds has turned a Massachusetts state forest's main attraction into an outdoor museum

The waters of Bashbish Falls plunge into a deep, greenish blue pool at the bottom of a narrow gorge between two forested ridges in southwestern Massachusetts. Near its shallower edges, the pool becomes a light emerald green. Surrounding the pool are great, flat gray rocks, which warm quickly under the summer sun. For years—probably for centuries—people have sprawled out on these stones to soak up the heat before diving into the cool water.

The falls (a series of closely spaced cascades that twists between the cliffs of the gorge) are almost 200 feet high. At the brink of the last cascade, a stubborn, diamond-shaped, granite and schist outcropping divides the stream into two 50-foot ribbons that plunge into the pool.

From a parking lot at the gorge's edge, a steep, rocky path winds down through a hemlock and hardwood forest to the falls and the pool. Near the end of the trail a large, intrusive sign, hanging from a cable suspended between two trees, admonishes in large letters: No Fires, No Camping, No Swimming. Smaller letters warn the reader: Use Trails on This Side of Fence. From the end of the path, the cliffs and the falls' white water are barely visible through the heavy foliage; in the opposite direction, the forested hills roll down to the Hudson River floodplain in New York.

Except for the waterfalls, the gorge, and the pools strung through it, Bashbish Brook is like many other streams in the Taconic range, which extends south from Vermont to the Hudson highlands in New York. Flowing westerly from a swamp a few miles upstream from the falls, the black water meanders between hummocks of tall brown sedge before it enters a lily-coated pond. The stream gathers momentum when it leaves the pond. By the time it has wound through a nearby meadow and into a forest, white water tumbles over boulders and fills small pools. Here, serious-minded spring fishermen in waders cast for trout, using tiny flies at the end of long curving lines. Not far from them, boys in bluejeans and sneakers, armed with hooks and worms, sink

by Christopher L. Hallowell

heavily weighted lines into promising-looking holes under big rocks.

People have long used all of the stream, but the gorge, the falls, and the pool have always attracted the greatest numbers. Recognizing the area's scenic value, the Massachusetts Department of Natural Resources in 1924 purchased some 400 surrounding acres for $5,500. During the 1960s, the state obtained 4,000 additional acres and named the entire area Mount Washington State Forest, after a nearby mountain. This acre-

Christopher L. Hallowell

age, together with the 6,000 acres of the adjoining Taconic State Park in New York, created a recreation area of approximately 10,500 acres. But the area was not heavily used; hikers and campers usually did not wander off the few trails and hunters entered the state forest only during the fall hunting season.

The gorge and the falls, often frequented by adventuring boys, romantic couples, and picnickers, has always been the favorite part of the state forest. But visits sometimes ended in unfortunate accidents and, occasionally, deaths. Most injuries occurred when people climbed over the high terrain or swam in the swift waters. In the past, however, such accidents were infrequent.

With the increased leisure time, greater relative wealth, and improved transportation of recent decades, more and more campers, hikers, and climbers—many seeking a hardier type of outing than picnicking—came to the gorge. Many of the visitors were inexperienced and reckless. Some climbed the schist and phyllite cliffs without knowing how easily these rock forms flake and crumble. When the ledges broke away, climbers often fell, sometimes to their deaths. Or they dislodged rocks that struck other climbers. Most of these accidents occurred late in the afternoon when, according to park rangers, visitors were either tired or tipsy from drinking. When accidents occurred, rangers, state police, and firemen from neighboring towns converged on the gorge to spend hours, often far into the night, extricating the injured and hauling them up the steep path on stretchers. In 1972, more than twenty men worked through an entire night to rescue a schoolteacher who fell from a cliff and broke his hip.

Sometimes, careless swimmers plunged into pools without realizing that rocks lay just under the surface. During the 1960s, two or three people died in climbing or swimming accidents each year. And each summer about twenty people with broken limbs, head injuries, or lacerations had to be carried out of the gorge.

The accidents, however, did not deter visitors. By 1968, the number had surpassed 6,000. Hoping to divert some of the future visitors from the falls area, the Massachusetts Department of Natural Resources set up an administrative office and a campsite near the source of the brook a few miles upstream from the falls

and assigned rangers to permanent duty. But most of the recreation area remained largely unused. Few visitors hiked the trails or back-packed into the campsite. Instead, they continued to flock to the gorge and the falls: 40,000 people visited them in 1970; 50,000 in 1972.

Many people came for the day with their picnic lunches; others camped near the pool. A few abused the area. Not finding a ready supply of deadwood for fires, they cut down live trees. But the green wood did not burn well and blackened logs lay scattered about. A few people stripped the branches from young hemlocks and laid them on the rocky ground for makeshift mattresses. Later, the branches turned brown and ugly. Some visitors littered. On a Monday morning after a summer weekend, papers, cans, and discarded food lay half-concealed between the rocks and under the leaves.

Even those who did not litter had an impact on the area. When they wandered off the trail, they often trampled delicate flowers, such as trillium, columbine, and cinquefoil, all of which had a long history of flourishing in the gorge. They also disturbed the thin topsoil on slopes above the stream. The runoff from downpours carried the soil into the pools, exposing patches of bedrock on the banks. The waters of the stream became clouded with the runoff and with the soaps and detergents that campers used to wash themselves and their dishes.

To stop the ruination of the scenery and to prevent tourists from hurting themselves and others, the Department of Natural Resources in 1973 constructed a 3,500-foot, steel and cable fence around the top of the cliffs and down to the stream just above the falls. Snaking among the ledges and along the top of the cliffs, the gleaming fence is a jarring sight against the horizontally aligned rocks and the soft foliage. Regularly spaced signs all along the fence's perimeter warn visitors not to leave the trail around the gorge.

On summer weekends, four uniformed rangers patrol the area around the falls. Only looking is allowed: no swimming, no littering, no fires, no camping, no walking off the trails. Anyone committing an infraction of the regulations can be arrested, fined $2,500, and imprisoned for six months. But the rangers usually just eject offenders from the area.

The natural beauty of Bashbish Falls and the gorge now seems safe from the destruction that crowds so often bring with them. The sturdy fence, the signs, and the decisive rangers prevent tourists from injuring themselves and each other. Some 60,000 persons visited the gorge in the summer of 1974, with only one minor injury reported. The area around the falls is free of debris, the water sparkles, and in the spring, wildflowers grow undisturbed across the forest floor.

Between 75,000 and 100,000 people filed into the gorge last year. But they viewed the scenery in much the same way that museumgoers gaze at dioramas. The only physical effort possible on a visit to the falls is the short walk along the path between the pool and the parking lot.

Summer visitors carefully pick their way down this path, many wear bathing suits and towels draped casually around their necks. Their chatter and laughter become more voluble as the falls roar louder. But when confronted by the big sign near the end of the trail, many of them stop, stare at it, and murmur among themselves. When rangers, usually patrolling near the sign, and visitors come upon each other, the visitors often act like ill-at-ease guests. They nod at the rangers, give them little smiles, and continue down to the edge of the pool.

On nice days spectators cover the flat rocks; most stare passively at the white ribbons hurtling into the dark water. Newcomers may mill about for a few moments, trying to find a good viewing space, but they usually do not have to maneuver for long because people are constantly coming and going. Once settled, most people look at the falls for a few minutes and then begin to stare about restlessly. Some snap a few photographs. Youngsters often jump from rock to rock beside the pool, in a directionless manner suggesting boredom.

Many visitors approach the rangers to ask them about the restrictions. The rangers invariably tell them about the accidents and past abuses. Nodding in subdued understanding, the visitors take a last look at the falls, turn their backs on the No Fires, No Camping, No Swimming sign and trudge back to their cars in the parking lot.

Christopher L. Hallowell is an associate editor of Natural History.

Sky Reporter

Missing Matter

Significant amounts of several elements are unaccounted for in the galactic gas. Where has the material gone?

Studies with a space telescope show that iron and certain other common elements are in short supply in the thin gas that pervades our galaxy. Theorists disagree on where the missing atoms are, but suggest various possibilities: they may have condensed into microscopic dust grains, they may have accumulated into icy baseballs floating between the stars, or they may have become concentrated in the heads of interstellar comets.

In 1904, a German astronomer at the Potsdam Observatory discovered a curious effect in the spectrum of the star Mintaka (from the Arabic *Al Mintakah,* for "the belt"), located in Orion's belt. As expected, the spectrum contained a familiar pattern of dark lines owing to the absorption of the star's light at particular wavelengths by the various elements present in it. Further, because Mintaka is a member of a binary star system and thus moves around an orbit, the lines in its spectrum were seen to shift back and forth, moving toward red wavelengths as the star moved away from the earth and toward blue wavelengths as it returned on the opposite side of its orbit. This is a well-known phenomenon caused by the Doppler effect. An unexpected finding of the German astronomer Johannes Franz Hartmann, however, was that "*the calcium line . . . does not share in the periodic displacements of the lines caused by the orbital motion of the star. . . .*" Hartmann stressed the importance of this result by publishing those words in italics in *The Astrophysical Journal.* If the calcium line did not share the displacements of the other lines, then the calcium atoms responsible for the line clearly did not share the orbital motion of the star. Hartmann therefore concluded that the calcium vapor responsible for the spectral line must be located somewhere in space between the earth and Orion.

Since 1904, astronomers have found other elements in space in addition to calcium and have thereby identified a complex distribution of interstellar gas. With optical and radio telescopes, they have determined the spatial properties of this gas; for example, its tendency to be concentrated in the spiral arms of our Milky Way galaxy and to form local condensations, or "interstellar clouds." The gas is an extremely tenuous medium, thinner than the best laboratory vacuum; nevertheless its temperature range, density, and other pertinent properties have also been determined.

The importance of interstellar gas has grown over the years as new concepts of the origin of stars were formulated and it became clear to most scientists that stars are born by condensation from the clouds of the interstellar medium. At the same time it was accepted that much of the material of the stars is recycled back into space through the steady emanation of particles from the outer layers of stars, such as the "solar wind" of our own sun, as well as by eruptions and other processes. However, a vital test of these concepts remained to be made. If the stars are formed from the interstellar gas, then their chemical composition should resemble that of the gas. Unfortunately, some of the key elements in the interstellar gas cannot be detected by the conventional techniques of ground-based astronomy; their identifying spectral lines are in the ultraviolet wavelengths that are absorbed in the earth's atmosphere and thus cannot reach the observatories below.

by Stephen P. Maran

It first became possible to attack this problem in recent years when ultraviolet instruments were launched for brief intervals of observation on rockets that attain high altitudes in the atmosphere. But the greatest progress has come since August 21, 1972, when NASA launched the *Copernicus* satellite, one of the Orbiting Astronomical Observatories, carrying a 32-inch ultraviolet telescope. The satellite attained a virtually circular orbit at about 460 miles above the surface of the earth. At that altitude, *Copernicus* is outside the great bulk of our atmosphere and can observe the ultraviolet light from a great many celestial objects. Its onboard telescope was specially equipped by Princeton University astronomers to investigate the interstellar gas.

Among the key results of the *Copernicus*'s observations was the discovery that the amounts of at least ten elements are significantly smaller in the interstellar gas than in the stars. The measurements were made relative to hydrogen, known to be the most common substance in the stars and consequently used as a convenient standard of comparison when measuring the trace amounts in which most other elements are present in the universe. The "missing" matter in the interstellar gas includes carbon, nitrogen, oxygen, and iron. Estimates of the underabundance of iron, for example, range anywhere from a factor of 5 to a factor of 100. Where has all the iron gone?

Astrophysicists believe that the missing matter is, in fact, present in interstellar space but exists in a physical condition that does not allow it to absorb light in the manner of the vapor that produces the spectral lines at discrete wavelengths observed by *Copernicus*. The most obvious idea is that much of the gas has cooled and condensed to a solid state. Indeed, the presence of tiny solid particles in space has been recognized since the 1930s, when an astronomer at Lick Observatory in California found that the light from star clusters was dimmed by intervening matter. Although these "interstellar dust grains" do not produce spectral lines, they are reponsible for a general diminution of starlight received on the earth—an effect that tends to block out more of the shorter, blue wavelengths than the longer, red wavelengths. The situation is somewhat analogous to the reddening effect a large city's smog layer has on sunlight, which has led astronomers occasionally to refer to the dust grains of space as "interstellar smog." Direct proof of the presence in space of dark matter, assumed to be concentrations of dust grains, also comes from photographs of certain galactic regions where dark structures are silhouetted against bright starry or nebular backgrounds.

According to George B. Field, an authority on interstellar matter who directs the Center for Astrophysics in Cambridge, Massachusetts, the iron and other substances that are depleted in the interstellar gas are simply stored in solid form in the dust grains. His reasoning is based in part on the prevailing theory of the origin of the dust. Just as much of the particulate matter in urban smog comes from the smokestacks of industrial furnaces, so interstellar dust grains are believed to originate in the hot gas flowing out from stars as some of it cools and condenses in interstellar space. In fact, some astronomers claim to have found indications that dust particles are forming in the outer regions of our own sun's atmosphere.

Field believes that the respective amounts of missing elements are precisely what you would expect from such a condensation process, and he has designed a model dust grain to account for the observations. In his

theory, the materials that vaporize at the highest temperatures, such as iron and silicate rock compounds, condense first as the hot gas cools, producing dense cores about a millionth of an inch in diameter. Subsequently, the lighter atoms, such as hydrogen and oxygen, occasionally collide with those grain cores and may stick to them. Then, through processes of surface chemistry, the lighter atoms stuck on the grains combine with each other to form such compounds as H_2 (molecular hydrogen), OH (hydroxyl), and H_2O (water ice). The H_2 and some of the OH escape from the grains in the process of forming, thus accounting for the presence of these molecules in interstellar space; but the H_2O and other frozen molecules do not escape, instead, they build up an icy mantle around the dense grain cores.

This picture is consistent with radio astronomy observations that have revealed clouds of hydroxyl gas in our galaxy and with other studies made by the Princeton astronomers using *Copernicus*, which show that much of the interstellar hydrogen is actually in molecular rather than atomic form. Field goes on to compare his interstellar grain model to a microscopic world: "The interior of the grain, like that of the earth, is composed of iron and silicates. Its outer envelope, like the oceans of earth, is water. The whole is immersed in a gaseous atmosphere, and is bathed, like the earth, in ultraviolet light and cosmic radiation."

Other scientists, however, disagree. They do not believe that all of the missing material can be stored in interstellar grains and they suggest further that the "sticking process" may build up solid, icy structures much larger than a single microscopic grain. The theoretical dimensions of these icy objects range from those of a baseball to those of a comet. Objects of this type would not contribute to the interstellar dimming and reddening of starlight in the manner of widely diffused dust, nor would they be observable from the earth by any known method. In fact, even the comets of our own solar system are generally invisible from earth except when they come close enough to pass within the orbit of Jupiter.

The obvious objection to these theories is that they predict the existence of things in space that we cannot hope to record or measure. Hence they can only be checked by addi-

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tional theoretical calculations. On the other hand, we do find comets in the solar system and they do appear to contain such materials as dust grains, ice, and molecules that include hydroxyl and possibly even molecular hydrogen (see "A Funny Thing Happened to Comet Kohoutek," *Natural History*, March 1974).

Since there are comets in our solar system, presumably they also exist elsewhere in space. The question is, How many comets does each star have? Are there enough in our galaxy to explain the great amount of missing interstellar matter? Conventional estimates of the number of comets in our own solar system suggest that even if the billions of unseen comets that are assumed to orbit the sun beyond the distance of Pluto are included, the total would still not amount to more than from one to one thousand times the mass of the earth. That is actually a small amount of matter and not nearly enough to account for the depleted elements even if comets of equal number are associated with each of the other stars. On the other hand, a leading theory of the origin of the solar system, proposed by A. G. W. Cameron, a colleague of Field's at the Center for Astrophysics, suggests that there are far more comets beyond Pluto than previously recognized. If many more comets formed around the sun when it was born than have so far been credited, then comparable numbers of comets may have arisen around other stars at their births as well. Cameron believes that this assumption might explain the missing elements of the *Copernicus* data.

It seems likely that the so-called missing elements are not truly lost but can be accounted for by one or another version of these theories or by a combination of them. Certainly some of the unaccounted-for material must be located in dust grains, while some of it may exist in the form of larger objects, including comets. The medium of interstellar space gives rise to the stars and they, in turn, enrich that same medium with their own gaseous and particulate emissions. The life cycle of the galaxy must thus include "gas to gas" in addition to "dust to dust."

Stephen P. Maran is studying stars at the University of California in Los Angeles on temporary assignment from NASA's Goddard Space Center in Greenbelt, Maryland.

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by Raymond Sokolov

The Drinking Man's Pear

When the fresh fruit is out of season, there is a spirited alternative

I moot dye, so soore longeth me
To eten of the small peres grene.
Chaucer, *The Merchant's Tale*

God, we may assert, made little green pears so that we would long for them. If you yearn for the fleshy fruit of *Pyrus communis,* if your idea of paradise (no pun intended) is to sit with a blonde Eve- or Adam-figure by an ever-blooming espaliered pear tree, you join a long tradition that links pears and carnality in the Divine plan. As Kenneth A. Bleeth of Boston University pointed out in a recent number of *Harvard English Studies,* the pear lust of the heroine of *The Merchant's Tale* is only one example of a medieval commonplace: that the pear is an emblem of sexuality. Chaucer, Bleeth suggests, also meant to identify the pear as the "apple" of the Tree of Knowledge in the Garden of Eden, which "was sometimes regarded by medieval commentators as conveying specifically sexual knowledge."

Nowadays we may dismiss all this allegorico-horticultural allusion as unscientific or prescientific maundering. But in our supposedly more rational ordering of the garden of earthly delights, we also admit certain suggestive connections between the Edenic fruits. Linnaean classification puts Adam's apple and the pear in the same nomenclatural bushel: the Malaceae family. Some authorities have even lumped the two trees together in the same genus. More to the point, apple trees and pear trees both grow pomes. Their fruits, in other words, have the same structure. They each have papery or bony cores (endocarps) with several seeds and a thickened outer part (hypanthium).

The similarities between these two fruits are, indeed, so obvious that we may profitably take them in our stride and concentrate on the differences. Primarily, the alert eater notices that the ideal apple crunches while the ideal pear almost melts in his mouth. The pear also has a grittiness inherent in it. Perhaps graininess would better express the fundamental texture of pear flesh, which is not to be scorned on that account. On the contrary, a ripe pear is among the most elegant of desserts, just as it is.

The trouble is that pears come to perfection and then move on, in a trice, to repulsive, brown-blemished mealiness. You have to watch them carefully. This untoward flightiness may have prevented pears from competing successfully for public attention with their cousin apples. In 1944, for example, the United States produced 2.86 million tons of apples and only 0.76 million tons of pears. By 1973, the most recent year for which I have been able to get figures, apple production had risen to 3.10 million tons and the pear crop had fallen to 0.72 million tons. Furthermore, the hardy, storable apple has typically been eaten fresh more than the fragile pear. In 1973, 56 percent of the apple crop was sold unprocessed as compared to 42 percent of the pears.

Still, that means that a lot of Americans are enjoying the unsurpassable aroma of a lot of fresh pears. Mostly they are intoxicating themselves with Bartletts, far and away the most frequently available variety and almost always the kind that gets canned. For further adventures with the pear, in its many other shapes and styles, experiment with Hardys, Flemish Beauties, Comices, Boscs, and D'Anjous.

A person can spend a delicious fall and winter and part of the spring (the pear season stretches, sometimes, as far as May) savoring all the different russet and green and dappled, round and bumpy, and of course, pear-shaped, big and little pears. Pear connoisseurship is a simple pleasure and a cheap treat. Ripeness, as the poet said, is all you need to worry about. You will quickly learn to recognize the springy feel of a perfectly ripe pear. Real aficionados also peel their pears, because the thin skin contaminates the taste of the flesh.

In the winter of 1967, I learned a neat and, in its way, spectacular method of peeling pears at the table. An old and distinguished waiter in the belle epoque main dining room of the Paris Ritz noticed that I was about to cut into a model fruit in a callow manner sure to mangle the pear and to cover my hand and sleeve with juice. He offered assistance. While gypsy violins crooned discreetly at one end of the drafty and deserted restaurant, he deftly impaled the bottom of the pear on a fork. As a result, he could hold the fruit aloft in one hand and peel it with a knife in the other. Needless to say, the peel fell away in one lovely spiral and his hands stayed dry.

Some people also poach pears in wine or bake them in tarts or serve them with ice cream and chocolate sauce—a sundae called poire Belle Hélène after the Offenbach show. I suppose these are fine things to try, but they do seem supererogatory, since the fresh pear, pristine and unmeddled with, surpasses them by so great a measure.

Where the pear is concerned, we can dispense with culinary ingenuity, until the season begins to wane. Then, fortunately, there is an alternative, expensive but wonderful: pear brandy. I refer to the colorless "white alcohol" distilled from fermented pear mash, not to pear-flavored, sweet liqueurs or to perry, which is a hard pear cider. Real pear brandy—

Raymond Sokolov is a free-lance food writer and novelist.

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Bill Stanton, Magnum

or poire or poiré or poire Williams or poire Williamine or Birnengeist, as it is variously known—smells like a perfect pear and it is 86 proof, as strong a drink as bourbon.

Pear brandy of this type is a European specialty. I know of no American producer, although there is a rumor that someone is experimenting in the Pacific Northwest, where the pears are. Until he starts shipping bottles East, however, we will have to look to imports. The best of these, in my experience, is Swiss poire.

Recently I visited a pear distillery outside Sion, the wine center in the canton of the Valais, east of Geneva. Pears are trucked in green and allowed to ripen in the mountain air. The warehouse is gorgeous with pear aroma. Once the fruit is mature, it goes into an industrial blender that chops it into a purée. In a typical week, 25,000 liters of this elegant mash might be fermented in steel "barrels" with enameled linings. The process of converting pear sugar to alcohol (and carbon dioxide) is promoted by mixing brewers' yeast into the mash. The liquid bubbles away at a constant temperature of 77° F. (25° C.) for a week or until the bubbling stops. Then it goes into a modern still, in 250 kilogram batches.

Nothing that goes on in that still would surprise a Kentucky moonshiner, except the clear smooth liquid with the powerful aroma that drips out of the end of the still's system of copper tubing and filters and rectifying towers.

Basically, distillation is a method of evaporating and filtering away unwanted substances in order to purify the alcoholic component of pear mash or grain mash (for bourbon or Scotch) or wine (for cognac or brandy). It is possible to achieve perfection in this process: 100 percent neutral spirits, pure alcohol. But a 200 proof beverage has no taste or personality ("proof" is double the alcohol percentage of a liquid). And so some impurities are left in. That is why pear brandy tastes of pear. The distiller produces a fairly stiff potion that averages out at somewhere between 55 and 60 percent alcohol (110 to 120 proof). This is diluted to a standard 43 percent with distilled water (which has had its impurities filtered out in a similar still), so that it becomes that smooth and luxurious after-dinner drink on which the knowing batten.

Very special bottles of poire come with a whole pear inside. I used to think that, to achieve this, a glassblower had to blow a bottle around each pear. In fact, the trick is done in orchards, where you can observe the curious sight of pear trees decked out with bottles on their budding limbs. Even so, it is a tough trick. One Swiss company puts 65,000 bottles on pear boughs every season, but only succeeds in growing 15,000 to 20,000 pears in an average year. Then the pears that do grow have to be pickled in pure alcohol so that they won't affect the taste of the pear brandy in which they eventually come to rest. Once you have one of these pear-filled bottles, you need never buy another. The pear lasts indefinitely, and the bottle can be refilled from a new bottle without a pear. This dodge saves money and, as a reckless friend of mine points out, you are left with several fluid ounces of new poire to drink, on the spot, because there isn't room for a whole fifth in the bottle with the pear.

If you don't feel like throwing an expensive drunk on the excess, you might join me in improving a classic French cake, the savarin, with a syrup made from pear brandy instead of the customary rum. Savarins are circular and spongy molded cakes baked from a yeast-risen dough. They are served drenched in spirituous syrup because they imbibe liquid easily, and like so many of us, they improve once they

have imbibed. This improvement, with a poire syrup, is cause for exultation. You may wish to accompany your first (or indeed your subsequent) tastes with the traditional Romansh toast of the canton of Grisons: E Viva!

Le Savarin Valaisanne
(Savarin with Poire Williams Syrup)

- 1 package dry active yeast
- 1 cup plus 1 tablespoon sugar
- ½ teaspoon salt
- ½ cup lukewarm milk (110 degrees)
- 4 room temperature eggs, lightly beaten
- 2 cups flour, approximately
- 11 tablespoons butter, softened
- ½ cup pear brandy
- 6 ounces apricot preserves

1. Dissolve the yeast, the salt, and 3 tablespoons of the sugar in the milk.
2. Stir the eggs and then the flour into the yeast mixture. Beat for several minutes with a wooden spoon in order to produce a smooth, soft dough.
3. Let dough rise in a warm, draft-free place until it doubles in bulk. This may take anywhere from forty minutes to two hours. The ideal room temperature is about 80 degrees. Somewhat lower room temperatures slow, but do not cut off, the growth of the yeast, which produces the risen dough. In any case, cover the bowl.
4. Beat the butter into the risen dough (reserving a half-tablespoon).
5. Preheat the oven to 400 degrees.
6. Grease the inside of a 6-cup savarin mold with the reserved butter. Pack the dough into the mold as evenly as possible, and smooth the surface with a spoon. Let rise until the dough almost fills mold.
7. Bake the savarin for ten minutes in the middle of the oven. Then reduce the heat to 350 degrees and continue baking for about ten more minutes, at which point the cake should be nicely puffed up, browned and cooked (so that a trussing needle will pass through it and come out clean). Remove from oven and cool on a rack.
8. While the savarin cools, prepare the poire Williams syrup: dissolve 11 tablespoons of the sugar in 1⅓ cups of water and bring to a boil, at which point you pour in the pear brandy, remove the syrup from the stove, and let it cool.
9. Unmold the savarin onto a flat platter. Invert it once more, onto another platter so as to leave the top (browned) side up. Then cut off the brown top in a thin layer and discard (this facilitates the imbibition of syrup).
10. Pour the syrup into a skillet large enough to hold the savarin. Invert the savarin once more, leaving the cut side down. Now slide it gently into the skillet. Let it stand in the syrup for 30 minutes.
11. While waiting for imbibition to take place, sieve the apricot preserves and combine with the remaining 3 tablespoons of sugar in a saucepan.
12. Pour off excess syrup, if any, by tilting the skillet. Invert savarin onto a flat platter and then invert a second time onto a serving platter, cut side down (curved side up).
13. Heat the apricot-sugar mixture until it comes to a boil. Then, working quickly and gently with a pastry brush, cover the savarin with apricot glaze. Clean up drips and refrigerate until ready to serve. There is a natural temptation to fill the hole in the middle of the savarin. Some people pipe sweetened whipped cream into the void. Others chill a mousse there—or install a mound of hulled strawberries. All of these ideas are decorative, but they do overcrowd the palate with an excess of sensations, distracting attention from the ethereal vapors of the pear.

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Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun moves from Sagittarius into Capricornus about January 19, then into Aquarius by mid-February. This takes it northward at an accelerating pace from its most southerly position of late December. By mid-February, later sunsets and the increasing duration of daylight will be quite noticeable.

The best moonlight occurs about mid-month in both January and February. The crescent moon will show up in the evening sky during the first week of both months, waxing and setting later until the middle of the month, then waning and rising later in the night until a few days before month's end.

In January, first-quarter is on the 9th, full moon on the 16th, last-quarter on the 23rd, and new moon on the 31st. First-quarter moon appears again on February 8 and full moon on February 15.

Stars and Planets Winter stars are well placed in the early evenings. Orion, high and majestic in the south, is surrounded by a halo of bright stars that can be traced from Sirius, to its left, up through Procyon, Pollux, Castor, Capella, and around to Aldebaran. Exploring Orion and nearby Taurus with a small telescope or binoculars can be fascinating. On a clear, dark night, the great nebula (in Orion's "sword"), seen through binoculars, can appear as large as the full moon.

If you see some bright objects that seem out of place in this winter's sky, check them with our Star Map, which shows three planets looking for all the world as though they were part of the winter star display. Jupiter, brighter than anything else in the sky (except the moon), is in the southwest. Mars is above Orion, very close in appearance and brightness to the star Betelguese, at Orion's "left shoulder." And Saturn, near to, and in line with, Castor and Pollux, and of similar brightness, makes Gemini look like triplets rather than twins.

Venus, the brightest planet in the dawn sky, is low in the southeast for a few hours before sunrise. Mercury is also a morning star, but not well placed for viewing.

January 16–17: The moon is near Saturn both evenings, passing below the planet during the day of the 17th.

January 20: Three events occur today: Saturn is in opposition with the sun, keeping it above the horizon all night; the moon is at perigee, nearest earth; and Mars ends its retrograde movement and begins to move to the left (east) again, taking it away from nearby Aldebaran (in Taurus).

January 23: The bright object near the moon tonight is Spica, in Virgo.

January 28: Venus and the crescent moon will make a pretty sight in the southeast this morning at about dawn.

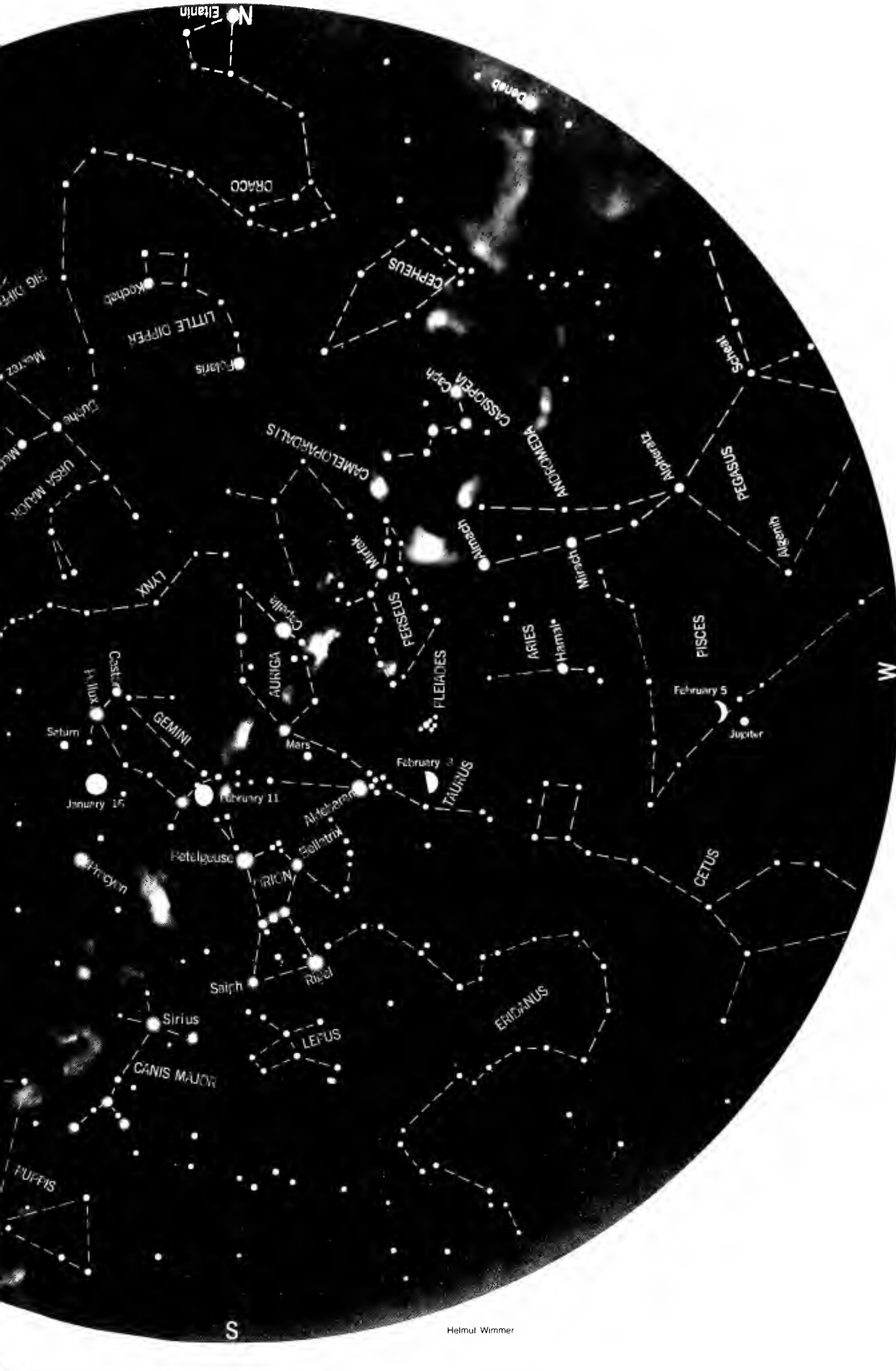
February 3: Mercury, having passed between the earth and the sun eleven days ago, becomes stationary and begins its normal (eastward) motion.

February 5: Look for Jupiter near the crescent moon at dusk tonight.

February 10: It is Mars's turn to be near the moon tonight, from dusk until both set well after midnight.

February 13: The nearly full moon rises near Saturn tonight. Pollux and Castor are the two stars higher than, and in line with, Saturn.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 10:20 P.M. on January 15; 9:15 P.M. on January 31; 8:15 P.M. on February 15; but it can also be used for an hour before and after those times.



Helmut Wimmer

The War Against Wildlife

The Politics of Extinction, by Lewis Regenstein. *Macmillan Publishing Co. $9.95; 280 pp., illus.*

The Environmental Protection Agency's prohibition of most domestic uses of DDT in 1972 and Congress's enactment of the Endangered Species Act of 1973 combined to raise public hopes that animals such as the brown pelican and others among the world's scarcest wildlife might yet be protected from extinction. The brown pelican and several other fish-eating birds (including the nation's symbol, the American bald eagle) suffered drastic declines in their numbers during the 1960s as a result of the gradual accumulation of DDT in the environment. Once ingested and metabolized, the chemical caused the eggs of the brown pelican to become extremely thin shelled or infertile. The obvious consequence was that more and more eggs were broken, fewer young were hatched, and total numbers dropped precipitously. In certain areas where the brown pelican had long flourished, such as coastal Louisiana, entire populations were completely eliminated.

The initial impact upon brown pelican populations of the ban on DDT seemed to indicate that public optimism had been justified. In many of those areas where the original populations had not been completely obliterated, remnant populations bounced back quickly. Their recovery was so good that state and federal wildlife authorities undertook to relocate some brown pelicans to the areas in which they had previously lived. Some of the relocation projects also showed signs of success. By April 1975, a relocated colony in Barataria Bay near Grand Isle, Louisiana, which had been started in 1968 with only 25 birds imported from Florida, had grown to more than 500 birds. Then in May the birds began to die, and in less than two months more than 80 percent of the restored colony was dead. The culprit this time, it is believed, was no longer DDT, but perhaps as many as eight other farm pesticides, including one known as endrin, which was found in all the dead birds that were examined. Apparently, spring flooding in the upper Mississippi valley had washed so much of the chemicals downstream at one time that a mass poisoning of Louisiana's brown pelicans resulted.

The example of the brown pelican is instructive in several respects for those who are concerned with the problem of extinction. First, it illustrates the critical vulnerability of most species considered to be endangered today. Such species have become so reduced in their numbers, so restricted in their ranges, and perhaps so weakened by the stresses of rapid environmental change that a single occurrence—an accidental oil spill, the draining of a swamp, or the accidental introduction of competing or predatory species—could deliver the final coup de grâce to entire local populations and perhaps to the entire species. The second, and more troublesome lesson to be learned from the brown pelican experience applies not just to presently endangered species but also to those species that are relatively abundant today and not considered endangered. This lesson is simply that the environmental consequences of any human activity, and not just those that employ relatively new and untested chemical technology, can never be foreseen with certainty and may, in retrospect, turn out to be immensely catastrophic. The final lesson, most ominous of all, is that the fight to save much of the world's vanishing wildlife may already be doomed by forces beyond any realistic prospect of short-term control, and that the most that its advocates can hope to gain is a few more years of survival before species after species disappears forever.

One who has not given up the fight on behalf of the world's wildlife is

by Michael J. Bean

Lewis Regenstein, a young, articulate environmental activist, who serves as executive vice-president of the Fund for Animals. Regenstein's new book, *The Politics of Extinction*, is the latest, and potentially the most effective, weapon to be used by the Fund in its battle against governmental and public indifference to the plight of endangered wildlife.

In Regenstein's view, a substantial share of the blame for the desperate state of much wildlife today can be placed at the feet of politicians who are unable to enact effective protective legislation, bureaucrats who are too timid to enforce vigorously the legislation that has been passed, and the various vested interests, most especially the hunting and firearms lobbies, which have bought off the politicians, intimidated the bureaucrats, and misled the public. Regenstein's argument is made most effectively in those chapters devoted to single animal types such as the wolf, the grizzly bear, and the prairie dog.

The literal war that has been waged against these animals has been fought, Regenstein argues convincingly, at the behest and for the exclusive benefit of the "sport" hunting lobby, the cattlemen's lobby, and the woolgrowers' lobby. Regenstein also explores the well-orchestrated efforts of still other commercial interests: the tuna industry's efforts to gut federal regulations designed to protect porpoises and dolphins, the fur industry's efforts to weaken and circumvent restrictions on the killing of seals and spotted cats, and the failure of both national and international bodies to check the excesses of the whaling industry.

The above examples and others that Regenstein discusses in detail are comprehensively documented, generally convincing, and always disturbing. In each instance, however, one can readily perceive that there is a clearly drawn conflict between a relatively specific commercial interest and an animal, the killing of which will either directly (as in the case of seals and spotted cats) or indirectly (as in the case of wolves and cougars) benefit that interest. The major shortcoming of Regenstein's book is that such clearly defined conflicts are probably atypical of the threats facing most endangered species, and Regenstein's examples may therefore be of limited utility in formulating a more generalized assessment of the causes and consequences of extinction. Similarly, his prescriptions may have little or no applicability to the difficult problem of preserving most endangered (and for that matter, nonendangered) species.

This is not to say that Regenstein has not written a very useful book. To the contrary, his principal examples, despite their selectivity, provide a sometimes shocking account of how the governmental apparatus can be manipulated by powerful commercial interests that do not have the slightest concern for ecological balance and seem incapable of comprehending the fundamental significance of extinction. *The Politics of Extinction* could well stimulate a substantial public awareness of, and concern for, the problem of saving endangered wildlife. By alerting a few politicians to the existence of a genuine constituency, which has frequently been regarded as little more than a nuisance, it could make the bureaucrats more concerned that they may ultimately be called to account for their inaction.

The Politics of Extinction, despite its substantial potential to serve as a catalyst for both private and public action, is not without its flaws, some minor and others not so minor. One of Regenstein's irritating habits is to be rather flip and to intersperse his arguments with tidbits of irrelevant information by which he attempts to stain his adversary with guilt by association. For example, Regenstein amply documents the fact that a great many organizations that are regarded

by the public as prowildlife conservation organizations are, in fact, strongly influenced and even financed by the National Rifle Association or others connected with the arms and munitions industry. These organizations, quite predictably, uniformly espouse the prohunting wildlife "management" philosophies of their benefactors. But having made this exposure quite effectively, Regenstein adds the wholly irrelevant and unnecessary barb that one such organization is represented by the same law firm that represented John Ehrlichman and H. R. Haldeman.

A more serious flaw is the inconsistent quality of Regenstein's documentation. Frequently his most dramatic claims are supported by no citation of authority whatsoever. Striking the balance between writing a book that is easy to read and one that is thoroughly documented with copious footnotes is never easy, but Regenstein can justly be criticized for opting too much for the former. His arguments depend too heavily upon the accuracy of the claims he makes to let them stand unsubstantiated.

In addition, there is the whole question of hunting. The Fund for Animals is one of the most openly antihunting organizations functioning today. Unfortunately, most of the debate in this country about hunting has taken place at the emotional rather than the rational level, and Regenstein never quite succeeds in elevating the argument. He dances around, but never quite attacks head on, the only rational argument that proponents of hunting have ever been able to offer in justification for their sport. That argument, quite simply, is that in the absence of natural predators, game animals would so quickly expand their numbers that starvation and disease would soon overcome them unless their numbers were kept in check by human hunting.

It has been rightly observed that the hunters' argument is more than a little self-serving, inasmuch as the essential premise is the absence of natural predators, and it is the hunters themselves who are principally responsible for the near obliteration of predatory animals such as the wolf, cougar, bear, and numerous others. Moreover, much as the hunter would like to cast himself in the role of nature's servant, performing the necessary task of natural selection, this sort of selection is actually unnatural and counterselective. The human hunter who passes up a big, strong buck for a sickly, infirm one is a most unusual hunter indeed.

Yet, valid as both these points are, they still do not constitute the principal argument that can be offered to rebut the hunter's favorite contention. That argument, put simply, is that the "starvation from overpopulation" thesis has been disingenuously applied across the board to all game species, whereas the only evidence that supports it is based upon a very few large animals, principally even-toed ungulates such as deer and caribou. There are convincing theoretical reasons why the largest animals in a given ecosystem, requiring the greatest area of supporting habitat, would be the first and perhaps the only animals to exhibit this sort of vulnerability to overpopulation. Moreover, there is ample evidence that unlike deer, many animals are able to keep their own numbers in check through some natural mechanism by which the reproductive rate is affected by the availability of food.

Instead of addressing what really is the bottom line argument in the debate about hunting, Regenstein wastes his readers' time and jeopardizes his own credibility by suggesting that hunters suffer from "a psychosexual imbalance" and in all likelihood "a latent homosexual tendency." Moreover, in his attempt to lay as much of the blame as he can at the feet of hunters, Regenstein leaves himself open to the charge that he accepts too uncritically one side of a hotly disputed debate among paleontologists about whether early man was the principal cause of the wave of extinctions of giant mammals that occurred around the globe about 10,000 years ago at the end of the Pleistocene Epoch. In fact, Regenstein at times seems willing to use either side of the debate, depending on how it fits his purpose.

The final flaw in *The Politics of Extinction*, which has already been alluded to, is that it is essentially a book about politics and not about extinction. To understand the importance of this distinction, it is only necessary to recall the example of the brown pelican. It would be very difficult for Regenstein to point a finger of blame at any politicians or bureaucrats for the tragedy of the brown pelicans. Granted that for a long time the manufacturers of DDT fought their utmost to block EPA's prohibition and are now fighting to have it lifted. Never-

theless, if the initial reports are correct and DDT is only one of nine pesticides that threaten the future of the brown pelican, we may yet have to face the prospect that either the brown pelican goes or we give up our pretensions of feeding the world and become a nation of organic farmers. Even that solution, it should be pointed out, would not have saved the hair-lipped sucker, a rather bizarre fish of the Ohio River Valley that became extinct in the early part of this century when the clearing of land for agricultural purposes in that area caused the formerly clear waters in which the sucker lived to become so clouded that it was no longer able to see the snails that made up its exclusive diet.

The sad truth is that for every species like the grizzly bear there are probably a dozen like the brown pelican and hair-lipped sucker. The world's population explosion requires that more and more land each year be cleared to house and feed it. Lewis Regenstein has studied the problem of extinction long enough to know that the greatest single threat to the future existence of most wildlife is the constantly accelerating pace of habitat destruction—both physical and chemical. He admits as much at one point in his book but then devotes less than five pages to the topic. The obvious reason is that the problem of habitat destruction is infinitely harder to deal with than the types of threats to wildlife that Regenstein treats. The villains are much more difficult to single out; the solutions much harder to articulate and to accept. We in the United States have often stated that we want to maintain our standard of living, feed the world's billions, and at the same time, protect our wildlife from extinction. One need not really study the matter too long before concluding that a serious question exists as to whether we can ever hope to accomplish all three. Yet if the problem of saving wildlife is regarded as Regenstein describes it, solely in terms of prodding a few politicians and bureaucrats into action, we run the risk of blithely assuming that we have at last found the key to the preservation of wildlife while the forces of extinction roll inexorably on.

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Additional Reading

Bald Eagle (p. 8)

The best single source of information on eagles and their raptor relatives is L. Brown and D. Amadon's two-volume work *Eagles, Hawks, and Falcons of the World* (New York: McGraw-Hill, 1968). Brown has also authored a shorter, less-expensive volume, entitled simply, *Eagles* (New York: Arco Publishing, 1970, $3.95). Wildlife writer George Laycock has recently published *Autumn of the Eagle* (New York: Charles Scribner's Sons, 1973, $6.95), which R. G. Raikow's *Wilson Bulletin* review characterizes: "An informative but engaging account of the life of the bald eagle and its decline and threatened extinction at the hands of mankind." Readers having access to a good university library should be able to obtain F. L. Beebe's "Field Studies of the Falconiformes (Vultures, Eagles, Hawks, and Falcons) of British Columbia" (*Occasional Papers of the British Columbia Provincial Museum*, 1974, no. 17, pp. 1–163). This fascinating monograph presents a storehouse of knowledge gleaned from a half-century of personal experience with the birds of prey of North America. David Zimmerman's recently published *To Save a Bird in Peril*, which provides ten accounts of people working to rescue rare birds from extinction, puts into perspective such problems as pesticide poisoning, habitat intrusion and destruction, and the introduction of unnatural predators. For related books and one additional account of the effects of pesticides on reproduction in raptors see "Return of the Osprey" by D. Puleston in the February 1975 *Natural History*.

Mesa Verde (p. 38)

A Guide to the National Parks: Their Landscape and Geology, by W. H. Matthews III (Garden City: Doubleday/Natural History Press, 1973, $5.95), provides good background material in a section on the only national park established for the express purpose of protecting archeological objects—Mesa Verde National Park. A special Southwest issue of *American Anthropologist* of August, 1954 (vol. 56, pp. 529–737), contains eleven classic papers, most of which are still of current and topical importance. In the *U.S. National Park Service Archeological Research Series*, several monographs have been issued that deal directly with the seven-year Wetherill Mesa Project. These include "The Archeological Survey of Wetherill Mesa," by A. C. Hayes (No. 7-A, 1964), which provides an over-all picture of the site prior to the intensive excavations and studies of the project; "Wetherill Mesa Excavations: Mug House, Mesa Verde National Park, Colorado," by A. H. Rohn (No. 7-D, 1971), specifically describing one archeological site; and "Wetherill Mesa Studies: Environment of Mesa Verde, Colorado," by J. A. Erdman et al. (No. 7-B, 1969), which deals with the present-day environment of the area. A series of twenty-nine articles by participants in the Wetherill Mesa Archeological Project may be found in *Memoirs of the Society of American Archaeology* (1965, no. 19). One paper, by H. Fritts et al. (pp. 101–121), on tree-ring studies that indicate climatic factors in the archaic environment of Wetherill Mesa may be compared with the Erdman et al. report of present-day ecology. R. Samuels's paper (pp. 175–179) on the health of the prehistoric Indians is based on analyses of preserved fecal remains and is particularly interesting from a methodological standpoint. Other papers deal with archeological evidence of animal and plant domestication; techniques used in agriculture, pottery, and weaving; and even "Postulation of Socio-economic Groups from Archaeological Evidence" (by A. H. Rohn, pp. 65–69).

Lost Wax Casting (p. 46)

Nepal: A Cultural and Physical Geography, by P. P. Karan and W. M. Jenkins (Lexington: University of Kentucky Press, 1960), which includes 35 maps and more than 60 illustrations, provides an understanding of the area and people. M. Singh's *Himalayan Art* (New York: Macmillan, 1971, $3.95), a revised, small-format edition of what was originally a $35 "art book," provides specific background material for the relationships of Nepalese artistic techniques and subject matter to other artisans of this area. Iconography, the representations of deities in a people's art work, is dealt with in A. K. Gordon's recently reprinted classic, *The Iconography of Tibetan Lamaism* (New York: Paragon Book Reprint Corp., 1967), and in "The Fierce and Erotic Gods of Buddhism," by C. Burrows (*Natural History*, 1972, vol. 81, no. 4, pp. 26–37). A recent new edition of Harry Jackson's *Lost Wax Bronze Casting: A Photographic Essay on This Antique and Venerable Art* (Flagstaff: Northland Press, 1972, $20.00) provides an exacting description of the lost wax technique of metal casting. See also P. J. Baus's "Men, Beeswax, and Molten Metal" (*Natural History*, 1965, vol. 74, no. 7, pp. 18–25).

Black Bears (p. 54)

A worldwide perspective may be gained from *Bears*, a short book by English naturalist Richard Perry (New York: Arco Publishing, 1970, $3.95); while *The World of the Black Bear*, by J. Van Wormer (Philadelphia: J. B. Lippincott,

1966, $5.95), is more specific, dealing only with *Ursus americanus* and providing excellent black-and-white photographs and an extensive reference section. "The Black Bear in the Spruce-Fir Forest," by C. J. Jonkel and I. McT. Cowan (*Wildlife Monographs*, 1971, no. 27, pp. 1–57, $1.70, available from The Wildlife Society, 3900 Wisconsin Ave. NW, Washington, D.C. 20016), details basic information—natural history, habitat, reproduction, behavior, population characteristics—on a high-density population in Montana. *Bears: Their Biology and Management*, edited by S. Herrero (IUCN Publications New Series No. 23), a selection of papers from an international conference, contains studies by Pelton and by Burghardt on black bear–human interactions, by S. Herrero on behavior and on evolution, and by other investigators on black bear reproduction, behavioral development, and population characteristics.

Locomotion (p. 64)

For a general introduction to the changes in structure and behavior that accompanied the evolution of *Homo sapiens*, see D. Pilbeam's *The Ascent of Man* (New York: Macmillan, 1972, $3.95) or the 2nd edition of J. E. Pfeiffer's *The Emergence of Man* (New York: Harper & Row, 1972, $6.95). Avoiding most of the technical jargon of the field and dealing with a vast quantity of data in an interpretive, yet essentially accurate, manner, the Pfeiffer book will be particularly useful to the layman. Stephen Jay Gould's November 1975 *Natural History* column, "Posture Maketh the Man," offers another viewpoint on one facet of such changes.

Examples of scientific reports bearing more directly on the subject of primate locomotion are: "Chimpanzee Bipedalism: Cineradiographic Analysis and Implications for the Evolution of Gait," by F. A. Jenkins (*Science*, 1972, vol. 178, pp.877–879); "Bipedal Walking of the Chimpanzee," by H. Elftman (*Journal of Mammalogy*, 1944, vol. 25, pp. 67–71); and "A Biomechanical Interpretation of the Pelvis of *Australopithecus*," by A. L. Zihlman and W. S. Hunter (*Folia Primatolgica*, 1972, vol. 18, pp. 1–19). *Walking and Limping: A Study of Normal and Pathological Walking*, by R. Ducroquet et al. (Philadelphia: J. B. Lippincott, 1968), is a series of detailed descriptions and interpretations of more than a hundred excellent line drawings taken from motion picture studies of human locomotion. Emphasis is placed on differences in hip rotation relating to pelvic structure and on the comparative approach to such topics as aging; comparisons between children first learning to walk and the aged and infirm losing their ability to walk offer a useful perspective on the issue of how gait reflects the psychology of the individual.

Fever (p. 70)

An engagingly written and well-illustrated history of the discovery and use (as well as abuse) of natural medicinal botanicals is found in G. Marks and W. K. Beatty's *The Medical Garden* (New York: Charles Scribner's Sons, 1971). This account of the earliest roots of the science of pharmacology includes the earliest recorded medicinal uses of the source of aspirin, now our most frequently used fever-reducing drug. H. C. Bolton's short book, *Evolution of the Thermometer: 1592 – 1743* (Easton: Chemical Publishing, 1900), and E. S. Taylor's more scholarly review article, "On the Origin of the Thermometer" (*Annals of Science*, 1942, vol. 5, pp. 129–156), trace the early history of temperature measuring devices, describing the change in attitude and use from a scientific oddity and aristocratic plaything to a precision instrument of the physician. Of two scholarly works providing for a better basic understanding of thermal physiology, John Bligh's *Temperature Regulation in Mammals and Other Vertebrates* (New York: American Elsevier, 1973) is the more technical, while K. Schmidt-Nielsen's *Animal Physiology: Adaptation and Environment* (New York: Cambridge University Press, 1975) gives more general information. "Fever," a review article published by E. Atkins and P. Bodel (*New England Journal of Medicine*, 1972, vol. 286, pp. 27–34), raised the question of the role of fever in disease and served as the impetus for Kluger's studies, which were first reported in "Fever and Survival" (*Science*, 1975, vol. 188, pp. 166–168). Details of the infectious processes that produce fevers are found in G. T. Keusch's "Malnutrition and Infection," which appeared in *Natural History* for November 1975.

Bashbish Falls (p. 76)

One traditional concern of environmentalists, the impact of man's leisure activities on the plant and animal life of natural areas, has been augmented in recent years by sociological and psychological studies of his behavior while enjoying nature. Representative studies include "The Play World of Camping: Research into the Social Meaning of Outdoor Recreation," by W. R. Burch, Jr. (*American Journal of Sociology*, 1965, vol. 70, pp. 604–612), and "A Typology of Outdoor Recreation Activity Preferences," by J. C. Hendee et al. (*Journal of Environmental Education*, 1971, vol. 3, pp. 28–34). An annotated bibliography of research in this area may be obtained from Wildland Recreation Research Project, Pacific Northwest Forest and Range Experiment Station, U.S. Dept. of Agriculture Forest Service, 4507 University Way NE, Seattle, Wash. 98105.

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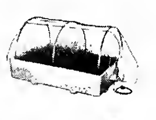

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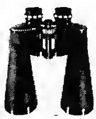

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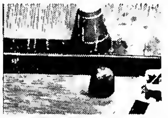

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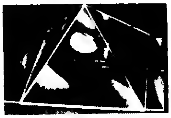

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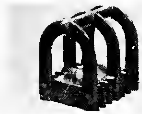

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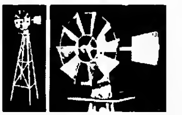

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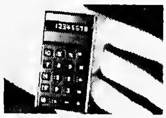

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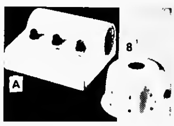

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Announcements

The World in a Hat continues through January in the Corner Gallery on the fourth floor of The American Museum of Natural History. This multimedia presentation, part fairy tale and part fact, shows how people use hats as emblems of status in religion, politics, sports, society, and jobs. Margaret Cooper's story is narrated by Bess Myerson, with drawings by Judith Rice.

Continuing through April in Gallery 77 of the Museum, **This Exhibit in Preparation** gives visitors a "behind the scenes" look at the techniques used to create the Museum's many marvelous dioramas and exhibits. Graphics, three-dimensional displays, and periodic demonstrations by artists, taxidermists, preparators, and model-makers reveal the inner workings of the Exhibition Department.

The Museum tour **East African Geological Safari**—a field study in geology, mineralogy, and paleoanthropology—will visit Kenya and Tanzania. The itinerary includes the Eastern Rift Valley, the lower slopes of Mount Kilimanjaro, the famed Olduvai Gorge, the pre-Acheulian hand ax find at Olorgesailie, and mines of tanzanite, corundum, amazonite, gaylussite, and meerschaum. On safari, trips will be made to Masai and Kikuyu villages, as well as to the Serengeti, Ngorongoro, and Mara game reserves. Two groups, led by Christopher Schuberth, lecturer in geology at the Museum and adjunct professor in geology at the City University of New York, are scheduled for July and August 1976. For details call the Department of Education at the Museum (212) 873-7507.

A new exhibition hall, **Hall of Mollusks and Mankind**, is open on the first floor of the Museum at the 77th Street Foyer entrance. This first, permanent interdisciplinary exhibition of its kind in the world focuses on the biology of mollusks, the meaning of shell symmetry, the use of shells and mollusks in scientific studies, and the use of shells as utensils, tools, religious symbols, ornaments, and art objects.

The following **Slide Lectures** will be held in the Education Hall at 2:00 P.M. on Tuesdays: *January 6*, New York Animal Life in Winter; *January 13*, Grand Canyon—A Geological River Journey; *January 20*, House Plants That Don't Talk Back; *January 27*, Wildlife of the Eastern Mountains.

At the **Hayden Planetarium** of the Museum, "The Christmas Sky," continuing through January 5, is a December tradition that examines the nature of the Star of the Magi. After a tour of our modern sky, the planetarium projector, used as a time machine, travels back 2,000 years and explores the astronomical possibilities of the star. "The Final Frontier" opens January 7. This Sky Show takes us on a futuristic voyage to the outer reaches of space aboard the nuclear-propelled spacecraft *Eratosthenes*. On this trip, the ship encounters strange planets, double stars, stellar novae, other galaxies, neutron stars, and mysterious black holes. Shows begin at 2:00 P.M. and 3:00 P.M. during the week, with more frequent showings on weekends. Admission is $1.75 for adults and $1.00 for children.

Robert G. Goelet has been elected the eighth president of The American Museum of Natural History. A trustee since 1958, he succeeds Gardner D. Stout, who has retired after seven years of service as chief executive. Mr. Goelet, 52, could be a prototype of the proverbially long and active leader in the cultural community of New York and the nation. An early academic interest in history and a passion for studying birds were the beginnings of an ever expanding inquiry into the natural sciences. Concurrently president of the New York Historical Society, he was, until recently, president of the New York Zoological Society and a director of the National Audubon Society. Mr. Goelet is a director of the Chemical Bank and a number of other business corporations.

He brings a special interest in ornithology, ichthyology and paleontology, but is no stranger to any of the Museum's programs. Under Mr. Goelet's active leadership, the full spectrum of research and education will benefit from his dedication to the advancement of scientific knowledge.

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NATURAL HISTORY

The amazing Mercedes-Benz 450SE. Take a good, close look. You've never seen anything like it.

Here's a walk-around checklist for one of the most important sedans ever engineered by Mercedes-Benz – or by anyone else. It'll help you see, firsthand, why the 450SE defies imitation ...and why it deserves your closest consideration.

1.
Start here. Look at the trunk space. An uncluttered 18.2 cubic feet. Spare tire is stored out of the way, flat under the floor, where it can also serve as an additional impact-absorbing device.

2.
Heated rear window. Automatic timer prevents wasted energy. Tinted glass all around. Standard equipment.

3.
Rain channels use airflow to divert rainwater from side and rear windows.

4.
Chrome strip/side protection molding is rubber-mounted to eliminate metal-to-metal contact.

5.
Interior is fully padded for safety and sumptuousness. Sealed against noise and heat. Four different sound-absorbing materials.

6.
Maximum-visibility windshield. All-around visibility in the 450SE totals 313°. Overlapping windshield wipers clear 73 percent of the entire windshield.

7.
Steel-belted radial tires. Standard equipment.

8.
Safety bumpers, rubber protected, hydraulic-regenerative. Front and rear.

9.
Halogen fog lights. Standard equipment.

10.
The outside rearview mirror. Distortion-free, folds full forward *and* rear for pedestrian safety. Large, inside rearview mirror folds and breaks away on impact for driver and passenger safety.

11.
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12.
Safety cone door locks. So strong that one of them can support the weight of the entire 450SE.

13.
Cockpit. Control panel has full instrumentation. Tachometer, quartz crystal clock, cruise control, AM/FM stereo radio, electrically operated windows are all standard equipment.

14.
Aerodynamically ribbed rear lights use airflow to stay clear in foul weather or on dusty roads.

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NATURAL HISTORY

Incorporating Nature Magazine
Vol. LXXXV, No. 2
February 1976

The American Museum of Natural History
Robert G. Goelet, President
Thomas D. Nicholson, Director

Cover: *Snow falls gently on the romantic Swiss village of Ostadt. At the same time, snow is accumulating on the Alpine peaks, creating a serious threat of avalanche. Photograph by Burt Glinn of Magnum. Story on page 44.*

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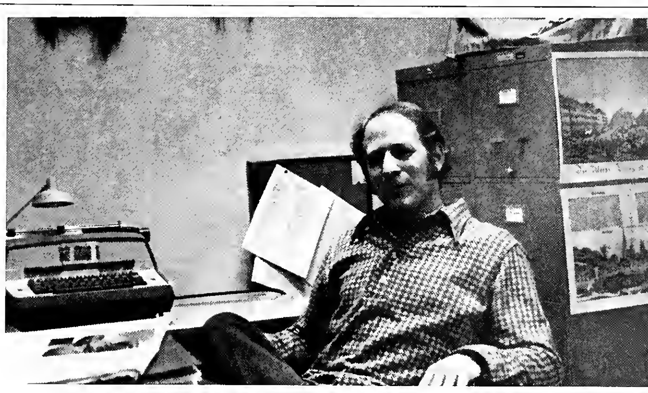
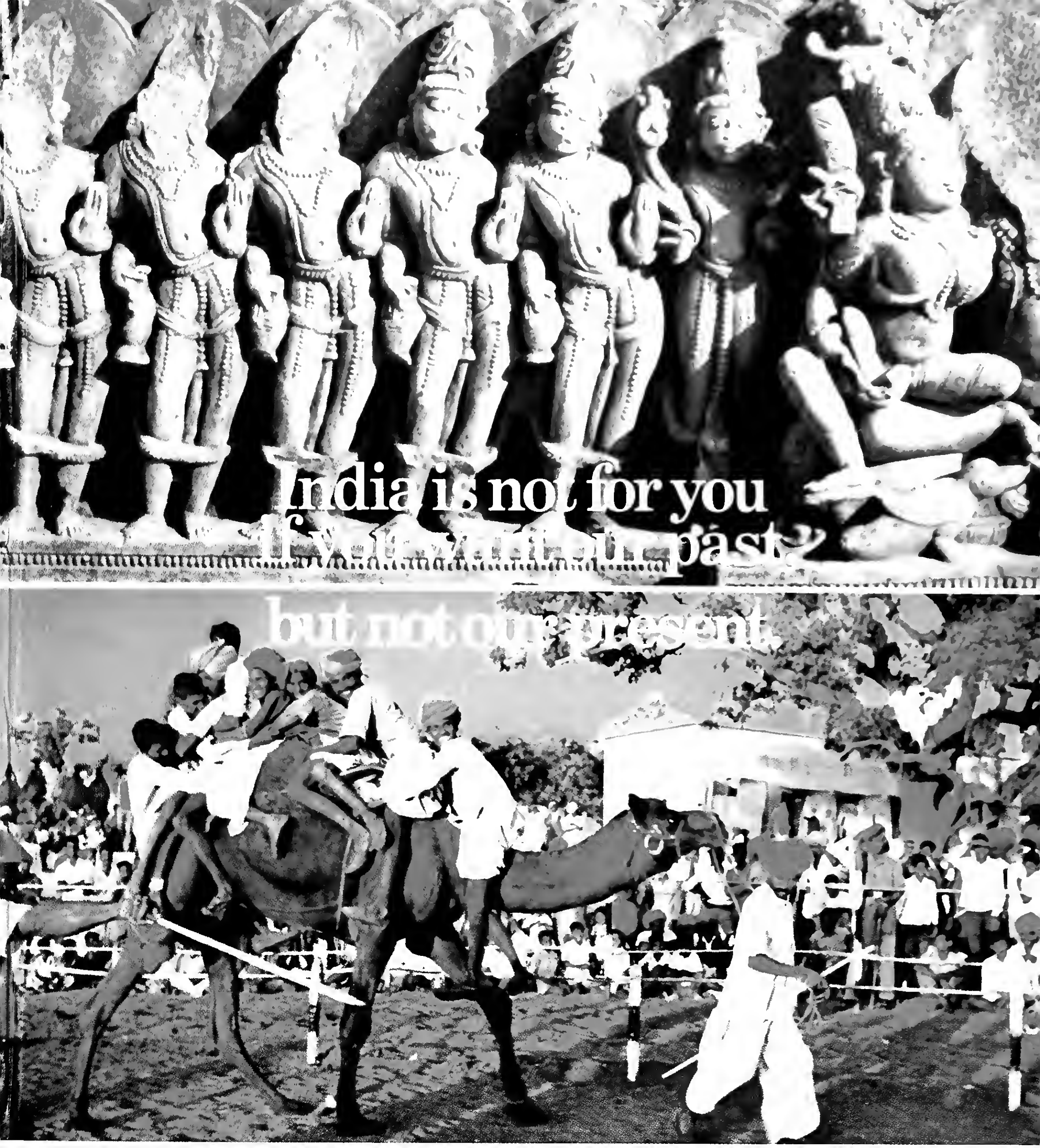
Authors

A research associate at the International Center for Medical Research, Johns Hopkins University, **Stephen C. Frantz** is examining basic rodent biology, ecology, and rodent–human relationships. He spent eighteen months in India looking into rodent behavior in grain warehouses and two years in Nepal collecting information on rats that infest houses, with particular emphasis on the factors in human life that affect rat success. Based on these studies, Frantz is developing ecologically sound approaches to the problems of pest control, food production, and waste management, which he hopes will be integrated into existing government programs.

An invitation from the United Nations Food and Agriculture Organization to serve as consultant on a development program for the Okavango Swamps led **Christopher H. Scholz** to Botswana. From boyhood on, his primary interest has been earthquakes. Scholz is professor of geology at Columbia University and a senior research associate at the university's Lamont-Doherty Geological Observatory in Palisades, New York. His attention is focused at present on the problems of earthquake prediction, a subject he has written about for this magazine (*see* "Toward Infallible Earthquake Prediction," May 1974).

When the Alpine village he was studying was struck by a severe avalanche, **John Friedl** was able to observe at firsthand the effect of natural disasters on such things as agricultural practices and social relationships. These observations became part of his doctoral research on culture change among former peasants in European society. An associate professor of anthropology at Ohio State University, Friedl has now turned his sights closer to home. He is exploring the problems of assimilation among Appalachian migrants and plans to look closely at their use of health care and other social services.





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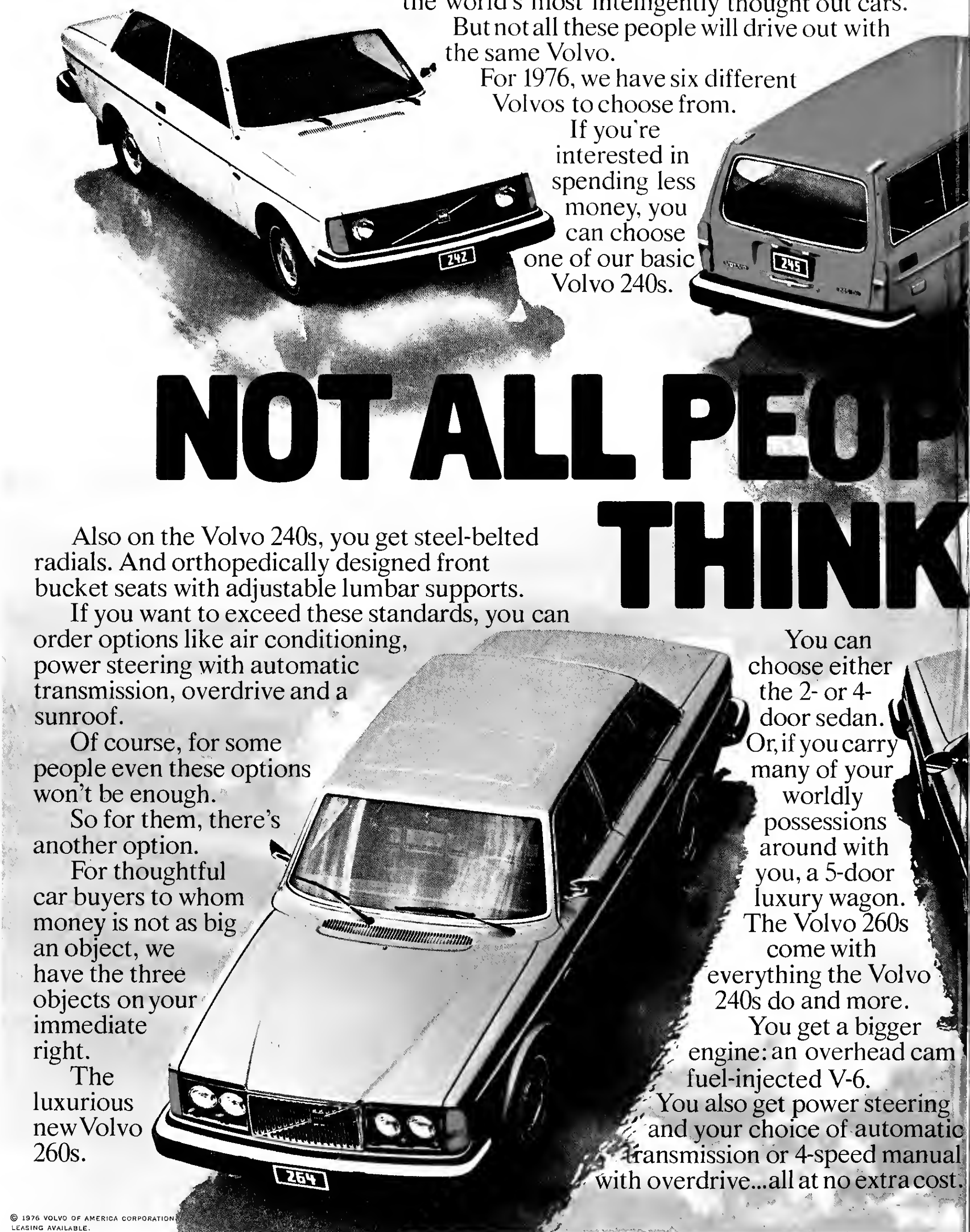
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ple who think.

Bats have been a research occupation for **Donna J. Howell** since her postdoctoral days at Princeton University's Auditory Laboratory. She has investigated the foraging strategies and energetics of nectar-feeding bats and is examining the biomechanics of bat legs in an attempt to learn why the creatures hang upside down. Howell has an adjunct appointment in vertebrate biology at the Florida State Museum in Gainesville, and between field trips to the Southwest, Mexico, Central America, and the West Indies in search of her bat subjects, she sings professionally with popular bands.

Peter F. Sale has been diving over coral reefs for the past ten years, but he never does it simply for pleasure. Instead, he devotes his time in the water to investigating the highly diverse fishes characteristic of reefs. A biology teacher at the University of Sydney in Australia, Sale spends some three months each year on the Great Barrier Reef, pursuing his interest in its fauna with a current emphasis on competition between plankton-feeding reef fish.

A designer, educator, and filmmaker, **Stanley Ira Hallet** was able to bring his many interests together when he spent the year 1971/72 as a Fulbright lecturer in Afghanistan. Although the chief purpose of his stay was to advise the fledgling School of Architecture at the University of Kabul, Hallet also worked with Afghan students in restoring the Char Chatta Bazaar, photographed Afghan houses and cities, and in collaboration with his wife, made a film on painted trucks. "The trucks were a natural subject," he says. "They helped explain what Afghanistan was all about." An associate professor of architecture at the graduate school of the University of Utah, Hallet plans to study twentieth-century American vernacular architecture, such as suburbs and shopping centers.

by Stephen C. Frantz

Rats in the Granary

Behind the success story of these ubiquitous rodents is a human tale of poorly kept buildings, torn sacks, and food we can ill afford to lose

At 3:00 A.M. I sat alone on the concrete floor of the grain godown (warehouse), amused by the group of seventeen rats that had just walked across my lap. As long as I remained quiet, the wild rats investigated me as they would any object—by sniffing, licking, and walking over me. That they would attack when threatened or cornered was evidenced by the stories of several laborers with telltale scars on their ankles and feet. For most of my observations I sat atop a 10-foot-high platform against one wall of the godown, but for detailed observations of behavior, I found it necessary to sit on the floor and "become a rat."

I had gone to India to study *Bandicota bengalensis*, the lesser bandicoot rat. Mine was the first naturalistic and systematic study of this animal's behavior and one of the few long-term behavior studies of wild rats in their natural habitat. There are numerous deterrents to such studies, not the least of which is the rats' nocturnal activity cycle and seamy living conditions. Most rodent biologists, as W. B. Jackson of Bowling Green State University has pointed out, "would rather examine traplines in the morning to determine where rats had been and what they had done . . . than spend the night attempting to be a part of their environment."

The adult lesser bandicoot rat is seven and a half inches long (excluding the tail), has a blunted snout, and rarely exceeds ten ounces in weight, but it otherwise resembles the ubiquitous common brown, or Norway, rat. The bandicoot is found throughout South Asia from Nepal to Sri Lanka and from Pakistan to Indonesia. In India this rat has traditionally been a field-inhabiting species, but in recent times it has apparently increased greatly in numbers and has displaced other major rat species in urban areas.

How much of this "take-over" is the result of bandicoots moving into urban areas and how much is the result of urban sprawl encroaching on the bandicoot habitat is still unclear. One thing that is clear, however, is that human food supplies are seriously threatened by any ecologically successful rat, a problem India cannot afford.

Regardless of cause, the lesser bandicoot has become the dominant rat in several large Indian cities, including Calcutta, Bombay, and Madras. This is significant because the lesser bandicoot has a greater reproductive potential than any other domestic rat. According to one study, more than half the adult female bandicoots in Calcutta were pregnant at any one time, and they averaged eleven pregnancies per year. I found that females become sexually mature at about sixty days of age and can produce their first litter after an additional twenty-two or so days.

Physiologically then, the lesser bandicoot can outbreed competing rodent species, which make up an exceedingly small proportion (less than 5 percent) of the total rat population of the study area. Certainly, this aspect of bandicoot biology indicated a good potential for ecologic success, but I needed to learn how the reproductive potential meshed with other aspects of the rat's life to effect that success.

My study was located in the grain godown district in Howrah, an industrial suburb across the Hooghly River from Calcutta. This general area has been important for trade and industry since Europeans began to frequent the Hooghly in the sixteenth century. Incidentally, the term "godown" is an old, corrupted form of the Malay word *godoṅ*, meaning "warehouse," and is widely used in Asia as well as Great Britain. In this district, small, dusty roads run between row upon row of old grain godowns and mills in various stages of disrepair. Most buildings are separated from each other by narrow passageways, an arrangement that provides the rats with numerous and well-dispersed resting places and travel routes.

I was immediately struck by the general poverty and lack of sanitation in the district. There is a dense human population with a disproportionate number of men, laborers who have migrated from outlying areas. Some people crowd into the limited living quarters usually provided in one or two rooms of a godown; other workers live along the sides of the street with little shelter. The street dwellers huddle completely under their thin blankets at night; somehow they manage this without suffocating at the same time. On cool evenings rats sometimes crawl under the blankets of these sleeping people, apparently to get warm.

Much of my time was spent inside a typical grain godown, a 30- by 55-foot structure, 15 feet high, with one

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tin and three brick walls and a cement floor. The godown was dark and dusty inside, hot for much of the year, and had the particularly unpleasant feature of harboring thousands of large brown cockroaches, which flew about in the dark and often ended up in my hair.

There are forty similar grain godowns within the study area, plus a few mustard oil mills. Bandicoot rats are not fond of the mustard seed itself, but they gnaw holes in the bags of seed to get at other grains inadvertently mixed in during harvest.

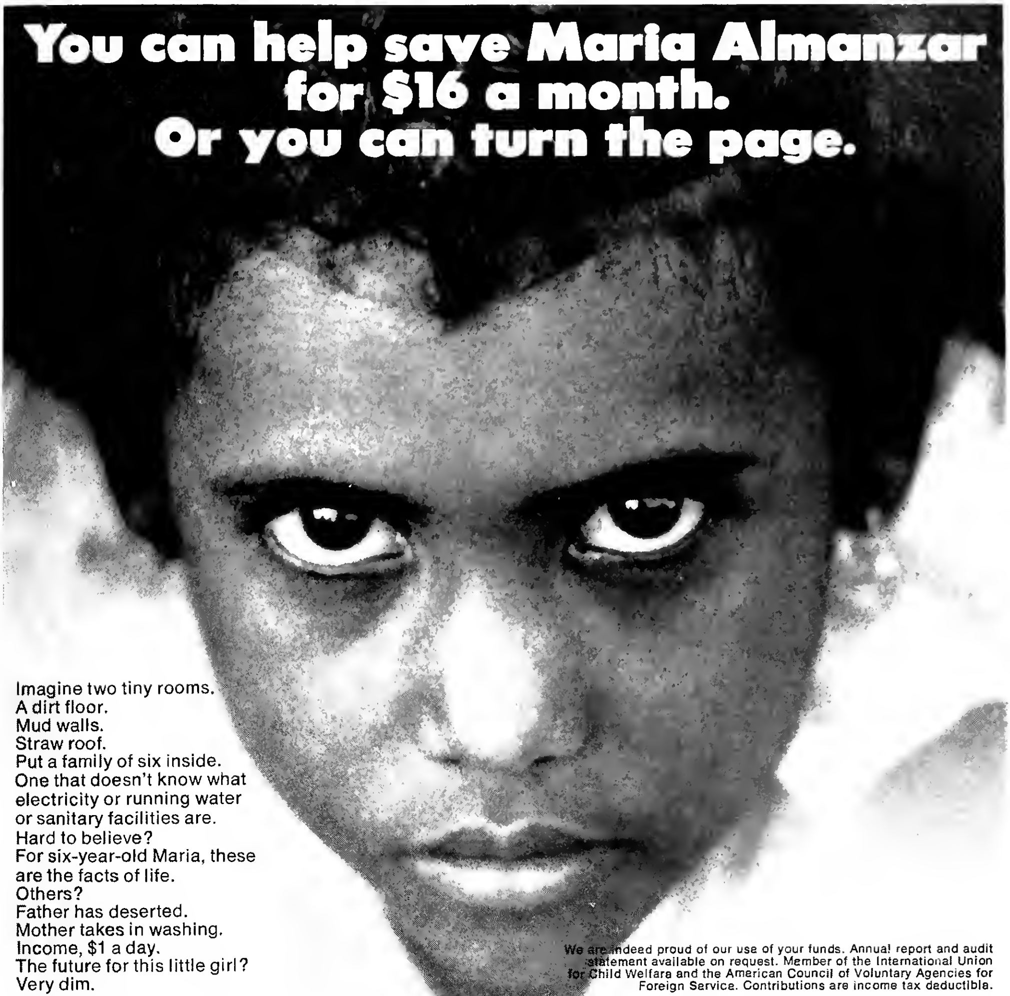
Nearly every building is pierced by ratholes; many have a main entrance hole gnawed through the base of the godown's front door. The rats take full advantage of man's poorly maintained habitat. The ground covering of the whole area is largely concrete or macadam, but concentrations of rat burrows occur wherever soil is found. Some animals live in the walls, foundations, or under the floors of godowns. To reach these areas, the rats gnaw through bricks and cement and, in more elaborate cases, into the wooden posts supporting the roof in order to reach the soil below the floor. In addition, some bandicoots find shelter under trash piles in the passageways between godowns.

Rats obtain water mostly from open drains and gutters, which often contain human sewage. On many nights I watched the animals drinking my own undiluted urine at a nearby latrine. With the exception of stored grain, the area has virtually no natural vegetation or other significant food source. The omnivorous diet of bandicoots includes garbage, insects, and dead birds, but they prefer wheat and rice, which are available in virtually unlimited supply. More than a hundred tons of grain could always be found in the immediate vicinity of the study godown. Grain is constantly being shifted in or out of the godowns, depending on the demands of the market. Every day laborers strain under 200-pound bags of grain, which they carry on their heads; the hooks they use damage the jute bags, causing small amounts of grain to be dropped wherever a bag is moved. The waste may be scavenged by a poor worker's family or eaten by the rats after dark.

Throughout the night a continual flow of bandicoots passes in and out of the godowns. The flow is not always equal in both directions and frequently results in large feeding aggregates of more than a hundred rats at a time in one room. The number of rats depends on various factors: the quantity of grain stored, time of day (rats prefer nighttime), and season (cool weather is more conducive to rat activity). Rat activity is also in-

In one grain warehouse in Calcutta, active adult rats eat about eleven pounds of rice a day. Additional consumption by pregnant females and young, plus waste, may mean a yearly loss of eight tons of grain.

Stephen C Frantz



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fluenced by conditions in adjacent godowns.

The general activity cycle of bandicoots probably has some underlying physiological control, as has been shown for many mammals, but environmental factors modify its expression. Human habits are especially important. At Curzon Park, a busy downtown intersection in Calcutta, for example, a colony of lesser bandicoot rats depends directly on man for food. To avail themselves of this opportunity, the rats are active only during the day, especially at lunchtime when office workers feed them peanuts and other tidbits, much as we feed squirrels or pigeons in our parks.

In sharp contrast, the godown bandicoots are active at night. The hustle and bustle of man's work makes daytime a generally unfavorable time for this small mammal to be active. No one particularly likes the godown bandicoots, and although no concerted systematic effort is made to harm them, someone will often kick a rat or even beat it to death. Since the rats cannot defend themselves very well, their small size is of considerable advantage in escaping from or avoiding their predators, of which man is the most significant. (Other predators, such as cats, dogs, owls, and kites, take very few rats in comparison to man.)

Avoidance, then, is an important part of the bandicoot's success. By nightfall the streets of the godown area are quiet and many people are asleep by 9:00 P.M. Thus, when their greatest predator, man, is inactive, the rats are able to move about freely; most bandicoots limit their activity to the period between 6:00 P.M. and 6:00 A.M., the inverse of man's activity cycle. Signals for ending a night's activity are available from a daily succession of events, beginning at about 4:00 A.M.: first, roosters crowing, later the sounds of pigeons and crows, and finally man's early morning toilet at 5:00 A.M.

The cover of darkness certainly provides the optimal time for rats to be active, but a small number of them can also be seen in the daytime. Their activity period is much less predictable than that of nocturnal rats and is governed mainly by the presence of man. If laborers are working in a godown, the rats avoid it during the day, but at night some rats will enter and hide in the corners, under bags, and in other inconspicuous spots.

During the day a few rats can be

found even in an empty godown, except during the hot summer months, March through June. Then the afternoon air temperature inside the godown can average 104°F. with more than 60 percent relative humidity; heat radiating from the tin roof adds to the extreme heat. Rats have poor physiological mechanisms for regulating their body temperature; to cool themselves, they depend largely on

A young girl gathers grain spilled from jute sacks damaged by the workmen's metal hooks. After dark, rats will eat what grain is left.

Stephen C Frantz

licking and spreading of saliva. Since water resources are restricted at this time, the rats prevent dehydration and overheating by avoiding empty godowns during the hot part of the day. They evidently spend the day in their burrows, which remain at a relatively constant temperature all year.

If a godown contains grain, rats will enter it on hot summer days, but they stay for only short periods and keep between the stacks of grain bags, which shield them from much of the radiant heat. Even on summer nights, with an average air temperature of 88° and 79 percent relative humidity, the bandicoots lose heat by stretching out on their bellies on the relatively cool concrete floor of the godown. In winter months (November through February), rats may be attracted to the godown, which remains above 63°, somewhat warmer than the temperature outdoors.

Intensity of lesser bandicoot rat activity is influenced not only by the actual quantity of grain within a godown but also by the length of time a particular quantity is held in storage. Frequent shifting, perhaps every few days, of abundant grain supplies encourages activity. As in other species of wild rats living under conditions of chronic disturbance, the bandicoots tend to explore novel situations of unfamiliar objects in familiar surroundings. An attractant in this situation might be the increase in grain odor that is released by moving bags of grain. This odor was obvious to me, and rats can perceive such odors with infinitely more accuracy than humans. This effect of grain odor concentration is compounded by residual odors, which persist after the grain in a godown has been shipped out. The high number of rats visiting a full godown will visit that site for at least the first night after it has been emptied. Their visits, however, are much shorter in duration, and on subsequent nights the numbers drop off exponentially. With the refilling of the godown, a large number of rats appear again, even on the first night.

What other cues are the bandicoots using to interpret the various changes in their environment? Since night vision in rats is not particularly acute, odor, as mentioned, probably plays an important role—not only grain odor but the odor of other rats gathered in a godown and the odor of rat trails, marked by their body oils and urogenital secretions as they move along a passageway. The presence of other rats in a godown also provides strong auditory cues—bandicoots eating grain in a closed area sound like a roomful of typewriters. If a rat detects other rats in a godown, grain is available and opportunities for social interactions exist. The latter is important because bandicoot rats are contact animals.

Thus, once a rat arrives at a particular godown he can evaluate its desirability. But how have these rats developed the ability to find food sources that change so erratically?

In a series of movement studies, I found that lesser bandicoot rats typically move around in an area 165 feet in diameter, and occasionally extend the diameter to 500 feet. Generally, this is a larger movement range than those of other species of rats in other urban areas. Some rats visit a particular godown more than once a night and revisit it on successive nights. With one or more grain godowns emptying at irregular intervals, the bandicoots are conditioned to wander regularly over a large area, visiting several godowns daily. This behavior enables the population to utilize new food sources when old ones are emptied or otherwise become unavailable. Protective runways, especially the narrow passages between buildings, allow the movements to extend farther than might occur in other circumstances. In fact, bandicoots living in fields apparently have a highly limited movement range.

How these rats deal with each other in order to allow this systematic exploitation of the resources in their environment without undue social stress is also interesting, particularly so because it contradicts some early studies that typified wild rats as savage or aggressive, especially to interlopers. After several months of work I realized there was considerably less fighting among the godown bandicoots, even at great densities, than one might expect from other studies. Nightly observations indicated that the rats had only limited territoriality. Adult females defended burrow entrances, especially against intrusion by adult males. Adult males sometimes defended areas around a burrow entrance, probably those with a sexually receptive female inside.

To further investigate this social phenomenon, I trapped adult bandicoots of both sexes, held them in the laboratory for several months and

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then released them, together with some laboratory-reared rats, back into the godown on several different nights when many rats were active. The resident rats tolerated all interlopers as well as they tolerated each other. In fact, within a few minutes of release, interlopers of both sexes were mating freely with resident rats.

Studies of wild rats of other species, conducted during the late 1940s and early 1950s, had led me to expect that resident rats would advance on the interlopers with some form of united, brutal aggression. When I repeated my release experiments in laboratory colonies of bandicoots, the results came closer to what I had expected to see in the godowns. While male residents mated with female interlopers, they vigorously attacked male strangers and would have killed them if I had not intervened. Female residents displayed a limited antagonism toward strangers of either sex.

An important difference in these two release experiments is that in the laboratory, a small number of rats were confined in a simple environment where mutual recognition of individuals was apparent. In the godown situation it would be quite difficult for residents to recognize a stranger per se. Large numbers of rats gather in feeding aggregates that fluctuate in size and membership.

Furthermore, since godown bandicoots wander over large distances, they must regularly encounter strange rats. Defense of their movement range by godown bandicoots would require an enormous expenditure of energy—to patrol the area, to fight with many interlopers, and to recover from the resultant bodily injuries. Obviously, territoriality would be selectively disadvantageous to these godown rat populations.

For similar reasons, there is no clear-cut social hierarchy among these rats. When two animals meet, they most often ignore one another, although they sometimes test for individual social rank in a bout of threat posturing or minor physical conflict. Also, some animals avoid others; if a fight is initiated, an animal can escape its attacker. Thus, in response to the high mobility of the godown population and to shifting environmental resources, harmful conflict is prevented mainly through the adoption of a relatively weak social-ranking organization and considerable tolerance of strangers. Conflict is probably also reduced since competition for food is unnecessary. With its ample, well-distributed grain supply, the godown situation must seem like a universe of food to even the most dense gathering of bandicoots.

The Food and Agriculture Organization of the United Nations has recently suggested ("guesstimated") that in the hot areas of the world, such as India, there are three rats for each human. To my knowledge, no one has ever attempted the formidable task of estimating the number of rats in a city like Calcutta. In the grain godown where I concentrated my studies, an average of 200 adult bandicoot rats were part of the nightly feeding aggregates. This excludes the small, young rats and many of the pregnant females, which apparently stay in their burrows or other harborages most of the time. In fact, this inactive group of animals could have been well in excess of the active adult population at any one time, and I may have been dealing with just the tip of a "population iceberg."

Bandicoots tend to feed in more than one godown in a night's activity, and there were more than forty such granaries in the study area. Each of these godowns could have supported a large rat population. Therefore, based on the above assumptions, I suspect it would be reasonable to suggest that my entire study area of roughly five acres supported at least 5,000 adult lesser bandicoot rats or approximately 10,000 bandicoots of all ages. Of course, these figures should not be applied to the other areas of metropolitan Calcutta for which we have no data.

To understand the significance to humans of these large numbers of bandicoots, we must go back to the study godown and look at the amount of grain required to feed those rats alone. Rice is the most abundant grain, and since each adult bandicoot can be expected to eat just under an ounce of rice a day, a total of about eleven pounds would be eaten by the estimated 200 adults that frequent the godown. Therefore, this active adult population of rats consumes more than two tons of food grain each year. This is enough to feed an average Indian his daily ration of rice for approximately eleven years! And this estimate of consumption is only for active adult bandicoots that use only a few grain godowns in a small area of just one city; in India this situation occurs over and over in many cities.

The above figures are outrageous enough, but they do not include the food grains eaten by the young and by many of the pregnant animals nor do they account for the waste of grain, which by FAO calculations is at least twice the amount eaten. Thus, the actual amount of grain made unavailable to man by the rats of the study godown could be more than four times my estimate, or eight tons annually. Of course, not all rats in India are so heavily dependent on the human food supply, but the conditions I observed in this study are representative for *stored* food grains. The implications are staggering!

At its present growth rate (which is not as rapid as many other nations), India alone adds about twelve million people a year to its population, which already makes up one-sixth of the world's human inhabitants. Since cereals and pulses are about 74 percent of the average Indian diet, with rice the preferred grain, it is obvious that these grains must be protected from the kind of serious damage rats impose. A reduction of such losses would be equivalent to an increase in cultivated acreage or to an increase in yield per acre.

Such an increase in the food supply could occur without additional destruction of forestlands and would circumvent much of the expense, and many of the long-term environmental degradative effects, of chemical fertilizers, pesticides, and herbicides usually used to produce high-yielding varieties of food grains. Relieving food shortages by saving food that is already produced should be more effective than growing more food in the Indo-Gangetic Plain. In fact, in most developing countries, food needs exceed actual supplies by only 6 percent or so; even a small improvement in such procedures as grain storage could close that gap.

The grain godown habitat is probably the urban equivalent of monoculture in agriculture; the great lack of diversity lends itself to the production of tremendous populations of opportunistic species—in this case, the bandicoot rat. As long as rats can successfully deal with their environment and its changes, they will thrive. I recently observed that bandicoots in Bombay have even developed the ability to climb service pipes in order to reach the upper floors of apartment buildings. In all of my Calcutta work

I never saw this; it is an adaptation for which bandicoots, unlike roof rats, lack the morphologic specialization of a climbing foot structure.

Of course, poisoning and trapping can remove individual rats from a population, but will not necessarily reduce the effective breeding population and will do nothing to reduce the capacity of the environment to support surviving or immigrant rodents. When such repressive efforts are discontinued, the population increases exponentially, often resulting in a worse problem. In Bombay, for example, the rat population continues to increase, although a million rats have been killed yearly for the last decade.

Environmental manipulation—including the elimination of rodent access to food, repair of structural defects, removal and disposal of trash accumulations, blockage of passages through which rodents might enter or leave a structure, and hygienic removal and disposal of garbage and sewage—is usually the most useful means of managing urban rodent populations. This approach lends itself well to appropriate technology, stressing low cost, intensive labor, and culturally adapted solutions to development problems. Such methods—similar to those advocated by Mahatma Gandhi more than thirty years ago—are not only environmentally sound but also conserve a developing country's foreign exchange and reduce its dependency on other powers. In the present case of rodent control in Calcutta, efforts of environmental manipulation should be concentrated on the grain godowns. Elimination of the primary resources—food and shelter—over time, will make them significant limiting factors, will increase competition for the remaining resources, and will result in a reduced rat population.

As a biologist, I find it necessary to respect rats for their ability to cope with the vagaries of existing in such a close relationship with humans. True, the rat is cunning, opportunistic, ecologically aggressive—but so is man. While this subject may arouse feelings of fear, hate, and disgust in the minds of many people, I think that to generally condemn rats because of their finely tuned adaptive capacity would be unjust. Domestic rats, such as lesser bandicoots, will adjust to the limits allowed by humans, and humans will suffer when those limits exceed their level of economic, medical, or esthetic tolerance. □

Human Babies as Embryos

Why are newborn humans far less developed and more helpless than the offspring of our primate ancestors?

Mel Allen, that irrepressible emcee of Yankee baseball during my youth, finally aroused my displeasure by overenthusiastic endorsement of his sponsors. I never balked when he referred to home runs as "Ballantine blasts," but my patience was strained one afternoon when DiMaggio missed the left field foul pole by an inch and Allen exclaimed: "Foul by the ash on a White Owl cigar." I hope that I won't inspire any similar displeasure by confessing that I read and enjoy *Natural History* and that I even sometimes get an idea for a column from its articles.

In the November 1975 issue, my friend Bob Martin wrote a piece on strategies of reproduction in primates. He focused upon the work of one of my favorite scientists—the idiosyncratic Swiss zoologist Adolf Portmann. In his voluminous studies, Portmann has identified two basic patterns in the reproductive strategies of mammals. Some mammals, usually designated by us as "primitive," have brief gestations and give birth to large litters of poorly developed young (tiny, hairless, helpless, and with unopened eyes and ears). Life-spans are short, brains small (relative to body size), and social behavior not well developed. Portmann refers to this pattern as altricial. On the other hand, many "advanced" mammals have long gestations, long life-spans, big brains, complex social behavior, and give birth to a few, well-developed babies capable, at least in part, of fending for themselves at birth. These traits mark the precocial mammals. In Portmann's vision of evolution as a process leading inexorably upward to greater spiritual development, the altricial pattern is primitive and preparatory to the higher precocial type that evolves along with enlarged brains. Most English-speaking evolutionists would reject this interpretation and link the basic patterns to immediate requirements of different modes of life. (I have often used this column to vent my own prejudices against equating evolution with "progress.") The altricial pattern, Martin argues, seems to correlate with marginal, fluctuating, and unstable environments in which animals do best by making as many offspring as they possibly can—so that some can weather the harshness and uncertainty of resources. The precocial pattern fits better with stable, tropical environments. Here, with more predictable resources, animals can invest their limited energy in a few, well-developed offspring.

Whatever the explanation, no one will deny that primates are the archetypical precocial mammals. Relative to body sizes, brains are biggest and gestation times and life-spans are longest among mammals. Litter sizes, in most cases, have been reduced to the absolute minimum of one. Babies are well developed and capable at birth. However, although Martin doesn't mention it, we encounter one obviously glaring and embarrassing exception—namely us. We share most of the precocial characters with our primate cousins—long life, large brains, and small litters. But our babies are as helpless and undeveloped at birth as those of most primitive altricial mammals. In fact, Portmann himself refers to human babies as "secondarily altricial." Why did this most precocial of all species in some traits (notably the brain) evolve a baby far less developed and more helpless than that of its primate ancestors?

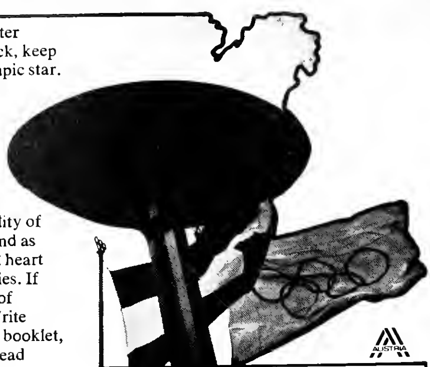
I will propose an answer to this question that is bound to strike most readers as patently absurd: Human babies are born as embryos, and embryos they remain for about the first nine months of life. If women gave birth when they "should"—after a gestation of about a year and a half—our babies would share the standard precocial features of other primates. This is Portmann's position, developed in a series of German articles during the 1940s and essentially unknown in this country. Ashley Montagu reached the same conclusion independently in a paper published in the *Journal of the American Medical Association* in October 1961. Oxford psychologist R. E. Passingham has championed it in a piece just published (late 1975) in the technical journal *Brain, Behavior and Evolution.* I also cast my lot with this select group in regarding the argument as basically correct.

The initial impression that such an argument can only be arrant nonsense arises from the length of human gestation. Gorillas and chimps may not be far behind, but human gestation is still the longest among primates. How then can I claim that human neonates are embryos because they are born (in some sense) too soon? The answer is that planetary days may not provide an appropriate measure of time in all biological calculations. Some questions can only be treated

properly when time is measured relatively in terms of an animal's own metabolism or developmental rate. For example, we know that mammalian life-spans vary from a few weeks to more than a century. But is this a "real" distinction in terms of a mammal's own perception of time and rate? Does a rat really live "less" than an elephant? Laws of scaling dictate that small, warm-blooded animals live at a faster pace than larger relatives (see my column of January 1974). The heart beats more rapidly and metabolism proceeds at a greatly elevated rate. In fact, for several criteria of relative time, all mammals live about the same amount. All, for example, breathe about the same number of times during their lives (small, short-lived mammals breathe more rapidly than larger, slow metabolizers).

In astronomical days, human gestation is long, but relative to human developmental rates, it is truncated and abbreviated. In my column for May 1975, I argued that a (if not the) major feature of human evolution has been the marked slowing up of our development. Our brains grow more slowly and for a longer time than those of other primates, our bones ossify much later, and the period of our childhood is greatly extended. In fact, we never reach the levels of development attained by most primates. Human adults retain, in several important respects, the juvenile traits of ancestral primates—an evolutionary phenomenon called neoteny. Neoteny has been crucial in human evolution for two reasons:

1. It provides a morphology adapted to our mode of life. We



have a large brain because rapid fetal growth rates continue in humans long after they have ceased in other primates. Our bulbous cranium and short face resemble those of juvenile primates, not the low-browed, long-faced adults (compare baby and adult chimpanzee on the November 1975 cover of *Natural History*). We can stand erect because our foramen magnum—the hole in our skull for attachment with the vertebral column—lies under our brain, not behind it as in four-footed mammals. The foramen magnum of fetal primates (and other mammals) lies under the brain, but migrates back during development.

2. The slow rate of our development has been important in itself, quite apart from the juvenile morphology that it permits us to retain as adults. We are primarily learning animals; we need a long period of dependent and flexible childhood to provide time for the cultural transmission that makes us human. If we matured and began to fend for ourselves as early as most other mammals, we would never develop the mental capacity that our neotenic brain permits.

Compared with other primates, we grow and develop at a snail's pace; yet our gestation period is but a few days longer than that of gorillas and chimpanzees. Relative to our own developmental rate, our gestation has been markedly shortened. If length of gestation had slowed down as much as the rest of our growth and development, human babies would be born anywhere from seven to eight months (Passingham's estimate) to a year (Portmann and Ashley Montagu's estimate) after the nine months actually spent *in utero*.

But am I not indulging in mere metaphor or trick of phrase in designating the human baby as "still an embryo"? I have just raised two of my own past this tender age, and have experienced all the joy and mystery of their mental and physical development—things that could never happen in a dark, confining womb. Still, I side with Portmann when I consider the data on their physical growth, for during their first year, human babies share the growth patterns of primate and mammalian fetuses, not of other primate babies. (The identification of certain growth patterns as either fetal or postnatal is not arbitrary. Postnatal

development is not a mere prolongation of fetal tendencies; birth is a time of marked discontinuity in many features.) Human neonates, for example, have not yet ossified the ends of limb bones or fingers; ossification centers are usually entirely absent in the finger bones of newborn humans. This level of ossification corresponds to the eighteenth fetal week of macaque monkeys. When macaques are born at 24 weeks, their limb bones are ossified to an extent not reached by humans until years after birth. More crucially, our brains continue to grow at rapid, fetal rates after birth. The brains of most mammals are essentially fully formed at birth. Other primates extend brain development into early postnatal growth. Macaque brains are 65 percent complete at birth, chimpanzees 40.5 percent. The brain of a human baby is only 23 percent of its final size at birth. Brains of chimps and gorillas reach 70 percent of final size early in the first year; we do not attain this value until early in our third year. Passingham writes: "Man's brain does not reach the proportion found for the chimpanzee at birth until around 6 months after birth. This time corresponds quite well with the time at which man would be expected to be born if this gestation period were as high a proportion of his development and life-span as it is in apes."

A. H. Schultz, probably the greatest primate anatomist of the century, summarized his comparative study of growth in primates by stating: "It is evident that human ontogeny is not unique in regard to the duration of life in utero, but that it has become highly specialized in the striking postponement of the completion of growth and of the onset of senility."

But why are human babies born before their time? Why has evolution extended our general development so greatly, but held our gestation time in check, thereby giving us an essentially embryonic baby? Why was gestation not equally prolonged with the rest of development? In Portmann's spiritual view of evolution, this precocious birth must be a function of mental requirements. He argues that humans, as learning animals, need to leave the dark, unchallenging womb to gain access, as flexible embryos, to the rich extrauterine environment of sights, smells, sounds, and touches.

But I believe (along with Ashley Montagu and Passingham) that a

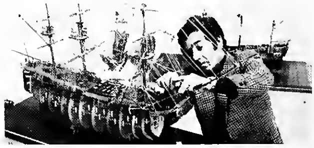
more important reason lies in a consideration that Portmann dismisses contemptuously as coarsely mechanical and materialistic. From what I have seen (although I cannot know for sure), human birth is a joyful experience when properly rescued from arrogant male physicians who seem to want total control over a process they cannot experience. Nonetheless, I do not think it can be denied that human birth is difficult compared with that of most other mammals. To put it rather grossly, it's a tight squeeze. We know that female primates can die in attempted childbirth when fetal heads are too large to pass through the pelvic canal. A. H. Schultz illustrates the stillborn fetus of a hamadryas baboon and the pelvic canal of its dead mother; the embryo's head is a good deal larger than the canal. Schultz concludes that fetal size is near its limit in this species: "While selection undoubtedly tends to favor large diameters of the female pelvis, it must also act against any prolongation of gestation or at least against unduly large newborns."

There are not, I am confident, many human females who could give birth successfully to a year-old baby.

The culprit in this tale is our most important evolutionary specialization, our large brain. In most mammals, brain growth is entirely a fetal phenomenon. But since the brain never gets very large, this poses no problem for birth. In larger-brained monkeys, growth is delayed somewhat to permit postnatal enlargement of the brain, but relative times of gestation need not be altered. Human brains, however, are so large that another strategy must be added for successful birth—gestation must be shortened relative to general development, and birth must occur when the brain is only one-fourth its final size.

Our brain has probably reached the end of its increase in size. The paramount trait of our evolution has finally limited its own potential for future growth. Barring some radical redesign of the female pelvis, we will have to make do with the brains we have if we want to be born at all. But, no matter. We can happily spend the next several millennia learning what to do with an immense potential that we have scarcely begun to understand or exploit.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



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Letters

John Canoe is Alive and Well

It was a pleasure to relate Robert Dirks's "Slaves' Holiday" [December 1975] to personal experience. A highlight on a cruise to the Bahamas was the Junkanoo Parade on New Year's Day. The Junkanoo are local bands of marchers, each band in a brightly colored papier-maché uniform, with stylistic masks on one of the marchers. Some of the masked figures wore elaborate headpieces. One that stood out was a stylized structure, as in a surrealistic house; another was a statue, angularly rendered, of a white person in the same clothing as the marchers. The word Junkanoo seems to be an obvious corruption of John Canoe. Thanks for a most pleasant article.

A.A. Catalano
Satellite Beach, Florida

Inspiration

I so much enjoyed Stephen Jay Gould's "Racism and Recapitulation" [June-July 1975], it inspired me to write the following poem:

Angels

Angels have no belly buttons
being unborn
No cord was ever severed to
seal them with mortality
Never do they in their
embryonic or juvenile
growth
recapitulate the adult stages
of their ancestors
knowing no womb
never were they graced with
paired gill slits
inherited from adult fish
to whom they might trace
their origins
Nor do they evidence the
slightest retention of
childish stages
of animal forebears
or contrariwise
any loss of adult structures
out of angel prehistory
having no antecedents
Indeed they exhibit no trace of
evolution

swift or slow
possessing no genes
to fashion enzymes for them and
speed or retard
their native rate of unfoldment
Neither do dark-skinned
infant angels
display a faster sensimotor
sophistication
and hence condemn themselves to
a lower I.Q.
when they mature
than fair-skinned ones will enjoy
for angels have no infants or
for that matter
skins

Even the distance between penis and
umbilicus
cannot be demonstrated to remain
small relative to height
throughout life in
black angels
for besides having no umbilici
they neither age nor may be
classified by sex
There are thus no females either
to retain sufficient
juvenile traits to prove them
not inferior to males

How awkward
for the sedulous geneticist
that a learned appeal
to nicely selected facts
is quite as futile for judging
the superiority of
one tribe or sex of angels
over another
as hunting for the belly button
on a cherub

John Moffitt
Poetry Editor
America

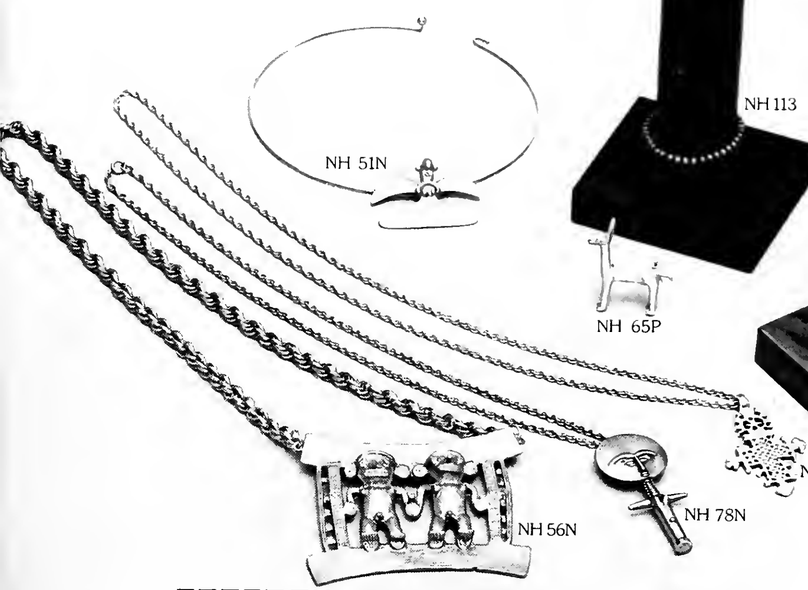
Football and Sex

While William Arens was writing "The Great American Football Ritual" [October 1975] he stared homosexuality straight in the face and pronounced it "ritual celibacy." And that's not only a euphemism, it's a sin of omission. His hypothetical anthropologist from another planet might be more interested in this oblique denial of the obvious, as I was, rather than in the ritual of football itself.

Of course, Mr. Arens is not totally to blame. Football players, given our current social climate, would probably deny that their behavior behind closed doors was anything less than missionary proper and pristine. (Most people do.) Certainly their managers and coaches would. In fact, most managers and coaches deny homosexuality so vehemently that, like Hamlet's player, they protesteth too much.

For those with an eye for art and a head for value.

Natural History Magazine invites you to enjoy some delectable collectables. Remarkable replicas cast from the originals on display at the American Museum of Natural History. It is difficult to tell these fine reproductions from the unique originals because each one is hand-cast and hand-finished by artist-craftsmen to duplicate the exact personality of the original. Right down to its precise size, texture, color and patina. Each replica comes with its own descriptive history. All jewelry is gift-boxed. Here truly are unusual gifts for those with an eye for art and a head for value.



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Mr. Arens correctly pointed out that the football team is a bastion of masculinity. Maleness is worshiped. Not only do the crowds worship it, but so do the team members. And given the opportunities of the members, it's only a few short steps from worship to adoration to love. If "hand holding, hugging, and bottom patting" are socially acceptable on the field, what might not be acceptable in the dark, behind closed doors and between close friends? To alleviate the worries of nervous managers and coaches, and possibly anxious anthropologists, let me point out that the athlete's homosexuality is the epitome of masculinity, for it excludes, absolutely, all femininity. It's the ultimate male compliment.

If the NFL and AFL were East African tribes, Mr. Arens would have had no difficulty in discussing their homosexuality and finding it normal.

Trent S. Knepper
New York, New York

Feminine cheerleaders and pompom girls provide a role model complementary to that of the masculine players. At Indiana we also have a girls' dancing troupe, The Redsteppers, which entertains at halftime. "Those curvaceous cuties with the gorgeous gams," as the announcer describes them, enhance a cultural stereotype dear to the audience—the decorative and subordinate woman, essential to a celebration of masculinity. Similar rituals accompany televised football from all over the country. They significantly reinforce sexual role models in our society.

Stephen L. Wailes
Bloomington, Indiana

More Ado About Starlings

I should like to add to a letter in your November 1975 issue regarding a reader who observed starlings perching upon cattle and feeding upon the face flies.

In the dialect of the counties of the north of England, the starling is called a shepster, a word which has its origins in Middle English or even Anglo-Saxon and relates this bird to the sheep which are to be found on the moors and in the valleys in that part of the country. It would appear that observers of such feeding habits have been around for a long time!

Vera Webb
Miami, Florida

Potlatch Problems

Paul Shankman's interesting article on Western Samoa and Potlatch [October 1975] leaves me wondering. The failure of the Potlatch experiment to live up to expectations seems akin to the failure of the tuna fishery in American Samoa. Why do the plans of sophisticated technologists of our industrial society miss their objectives so widely, as if they were really the plans of amateurs? It looks as if on a broadly systematic cost-benefit basis Potlatch's work would be found harmful to Western Samoa even if it made money for the company. Do you think there is *any* way for a moderately heavy industry to do business on a moderately small tropical island without destroying the original balance of everything?

William G. Mackenzie
Pebble Beach, California

Self-sufficient Farms

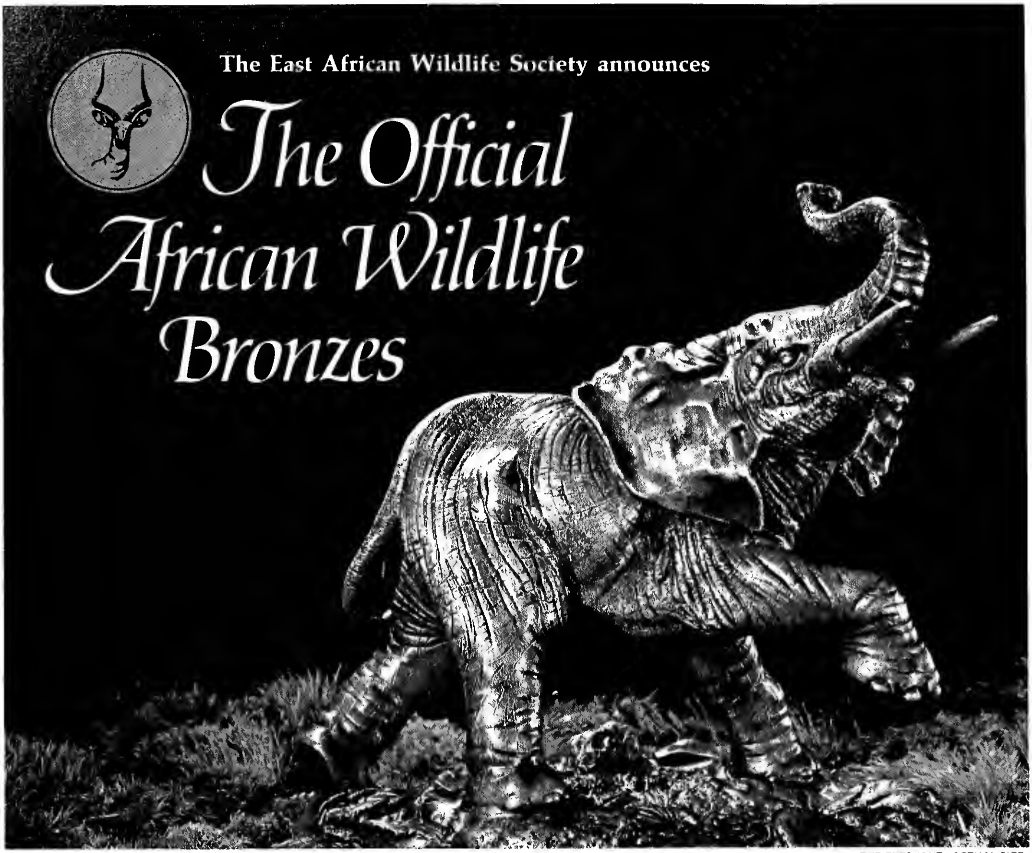
I enjoyed so much the article entitled "Alfred Moon's Farm" [November 1975]. It recalled to me with some nostalgia the stories my father told of his growing up on very much the same kind of farm in Vermont. My father had such a hatred of cows that it lasted all 69 years of his life.

Forty years ago I visited such a self-sufficient farm in Nova Scotia. It was considered a wealthy farm, but by our standards it was primitive.

The shopping list was always the same: salt, sugar, and tea. The eggs paid for the above.

H. Carlton Litchfield
Dedham, Massachusetts

Errata:
The caption accompanying the photograph of a desert iguana ("The Importance of Being Feverish," January 1976, page 71) indicated that all cold-blooded animals regulate their body temperature by moving to cool or warm spots. Many, but not all, ectotherms regulate temperature in this way. In the caption, page 72, the normal temperature range for the lizard should be between 100.4° and 102.2°. The statement in the author's column, page 4, that opossums do not get sick is misleading; while the animal has shown resistance to infection in the laboratory, the appropriate microorganism would probably make it sick.



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THE ELEPHANT - ACTUAL SIZE.

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Since the beginnings of time, the magnificent wild animals of Africa have challenged the imagination of artists. And no artistic medium has proved better suited to capturing the power and grace of these animals than bronze sculpture.

The tradition of bronze animal sculpture is one of the great traditions in the history of art—one that has come to be increasingly valued in our own time.

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The Official African Wildlife Bronzes

To create these sculptures, the artist traveled to Africa so that he could study the animals in their native habitat. Each sculpture is accurate to the most minute detail. Each is a superb original work of art, capturing the wild animal in a moment characteristic of its life in nature.

The Lion pauses in mid-motion. His limbs are stretched to the full, the long muscles sharply defined. His teeth are bared, his claws extended, and he is ready to break into the fearsome attack that has made him lord of the plains.

The Greater Kudu—a large African antelope with twisting horns—stands poised for flight, head turned to the wind. The carriage of his head, his flared nostrils, his taut leg muscles—all are captured with remarkable skill.

The Elephant is charging, ears out, trunk raised, turning as he comes. His tusks have all the power of his mighty body behind them. You can almost hear him trumpeting his anger.

The Giraffe has just heard some distant sound across the plain. He stands tall and attentive, head cocked, ready to break into a run or to defend himself with his powerful legs and hooves.

The Rhinoceros stands ready for battle. He fears no other creature. Descendant of the dinosaurs, his hide is like armor-plate, and his short legs can carry his bulk with surprising speed. Irritable, near-sighted, he low-

ers his formidable head with its dreaded horn, which was long thought to have magical properties.

The Cheetah — fastest of all animals — seems to flow over the ground. He is captured in a running bound, in the intensity of his pursuit.

Each sculpture is completely true to life, sculptured in superb and authentic detail. The hairs of the elephant's tail, and the markings of his hide . . . the ringlike serrations of the kudu's horns . . . the extended claws of the lion . . . each fine detail is sculptured with absolute fidelity.

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Each of these bronze sculptures will be individually hand-cast by the ancient "lost wax" *(cire perdue)* process. This casting technique is an art which has been passed from father to son through the generations. It is the same painstaking, time-consuming method that was used by Cellini, by Rodin, by Frederic Remington.

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Rifting in the Okavango Delta

by Christopher H. Scholz

Newly growing faults in southern Africa may indicate that the continent is slowly splitting apart

The Kalahari Desert is a vast expanse, roughly as big as Texas, that extends over the eastern part of South-West Africa (Namibia) and most of Botswana. Sparsely populated except for scattered cattle posts and the rare Bushman, it is for the most part extremely flat country whose monotonous terrain is only occasionally broken by the erosional remnants of Precambrian or early Paleozoic rocks, which form the stony hills known in Africa as kopjes. Despite its aridity and the brevity of its rainy seasons—approximately one month in November/December and from ten days to two weeks in March/April—the Kalahari supports an astonishing variety of game herds. This seeming paradox is due mainly to the existence on the northern fringes of the Kalahari of the largest and most fertile oasis in Africa: the great Okavango Swamps, or Delta.

The delta, a 6,500-square-mile area in the form of a rough equilateral triangle some 120 miles to a side, lies in the northwest corner of landlocked Botswana. It is the inland terminus of the Okavango River, the fourth longest river in southern Africa, but second only to the Zambezi in terms of volume of water.

The water of the delta is fresh—it is, in fact, the only natural surface freshwater in Botswana; the rest of the country's freshwater comes from boreholes. The delta, which is a tangle of islands, narrow channels, and lagoons, is therefore able to maintain a luxuriant plant growth in the sands of the Kalahari Desert. Its waterways are choked with papyrus, often five to ten feet high, and groves of mopani—a tropical African ironwood—are common on the islands. The clear freshwater is free of schistosomes (blood flukes) and other African parasites, and abounds in bream, pike, and tiger fish. Hippopotamus, crocodile, and many species of antelope, including the rare red lechwe and sitatunga, live in the delta. A flourishing birdlife embraces the Chobe fish eagle, crested barbets, lily trotters, cormorants, ibis, and spur-winged and dwarf geese. A variety of game lives in the delta's drier areas and around its fringes—lions, elephants, buffalo, and virtually all the antelopes, from the eland and kudu to the wildebeest and sable.

The endemic tsetse fly and mosquito have kept the human population of the delta very low, and it is thus a natural refuge and watering ground for the game of the Kalahari. Only the hardiest desert species of antelope, such as the gemsbok and springbok,

Peter Johnson, Natural History Photographic Agency

A reed cormorant finds safe cover for its nest in the Okavango Delta. There will also be plentiful fish to feed on.

The African spoonbill, known by its red face and bright pink legs, is another avian inhabitant of the delta.

All photographs by Peter Johnson

The delta is the only habitat in Botswana of the red lechwe, a species of antelope native to Africa seen here with a host of pelicans and storks

As evening falls, one tree roost is shared by a congregation of sacred ibis and little egrets.

Anthony Bannister

Often thought to be the most dangerous big game animal of the continent, the African buffalo lives in the floodplains of the delta as well as in other areas south of the Sahara.

Peter Johnson

A herd of hippopotamus swims in a channel near the delta. Hippo meat is eaten by many native peoples and the animal's hide is made into whips.

can maintain themselves year-round in the harsh environment of the central desert. The other game herds, which could not exist in the desert except for the swamps, are migratory, and the hub of their migrations is most often the Okavango Delta. During the rainy seasons, when the desert blooms, the migratory game live in the desert, but they return to the delta during the driest part of the year, from July through October. Even elephants and large aquatic mammals such as hippos migrate for hundreds of miles, following a series of shallow, circular, water-filled depressions known as pans. Pans range from about 30 to 300 feet in diameter and from one to several feet in depth. Formed by the trampling of elephants and hippos, pans actually serve as shallow wells, and many remain full of water the entire year, despite the total lack of rain during ten months.

Crucial to the Kalahari environment and to the future development of Botswana, the Okavango Delta—a vast preserve in its own right—is a natural freak. What in the world, it might be asked, is such a vast quantity of freshwater doing in a place like the Kalahari Desert?

South of the equator, the geography of Africa is typified by rivers that are fed by highland catchments and often traverse two-thirds of the continent to reach the sea, either the Atlantic or Indian Ocean. The Okavango River is an exception; its water never reaches the sea. It drains the southern highlands of Angola but flows barely 300 miles before ending in its inland delta, nearly in the middle of southern Africa. The area immediately to the west of the Okavango catchment drains into the South Atlantic; the area to the east is drained by the huge Zambezi River system, which flows to the Indian Ocean. There is evidence that in the geologically recent past, the Okavango also reached the Indian Ocean. But at some former time the river's flow was interrupted, and instead of stretching to the sea, the river ended in the vast Makgadikgadi (formerly Makarikari) salt flats in the northern Kalahari, where its waters evaporated, leaving salt deposits leached from the traversed terrain over an area as large as the present delta. The delta today is several hundred miles west of the salt flats, and only a small flow still reaches the Makgadikgadi from the Okavango River. The history of this river has thus been one of change and steady retrenchment into the interior of the continent. It is not the shrinking of the river itself, however, that is of greatest interest, but the processes that caused it.

River systems that do not reach the sea are called interior drainage systems. They occur most commonly in arid regions where evaporation is high and rainfall low. Instead of terminating at the sea, these systems flow to the lowest regional point of land, where the water evaporates leaving an accumulation of salt. If the flow is sufficient, a saline lake like the Great Salt Lake of Utah or the Caspian and Aral seas of central Asia will develop.

The Okavango River is unique among interior drainage systems since it flows into a freshwater delta that has almost no trace of salinity. This is because the Okavango Delta has two outlets by which a tiny volume of water flows eastward into the Makgadikgadi salt flats and southward into the saline Lake Ngami. Small as this outflow is, especially when compared to the net influx, it is sufficient to carry off most accumulated salt and to keep the waters of the delta fresh.

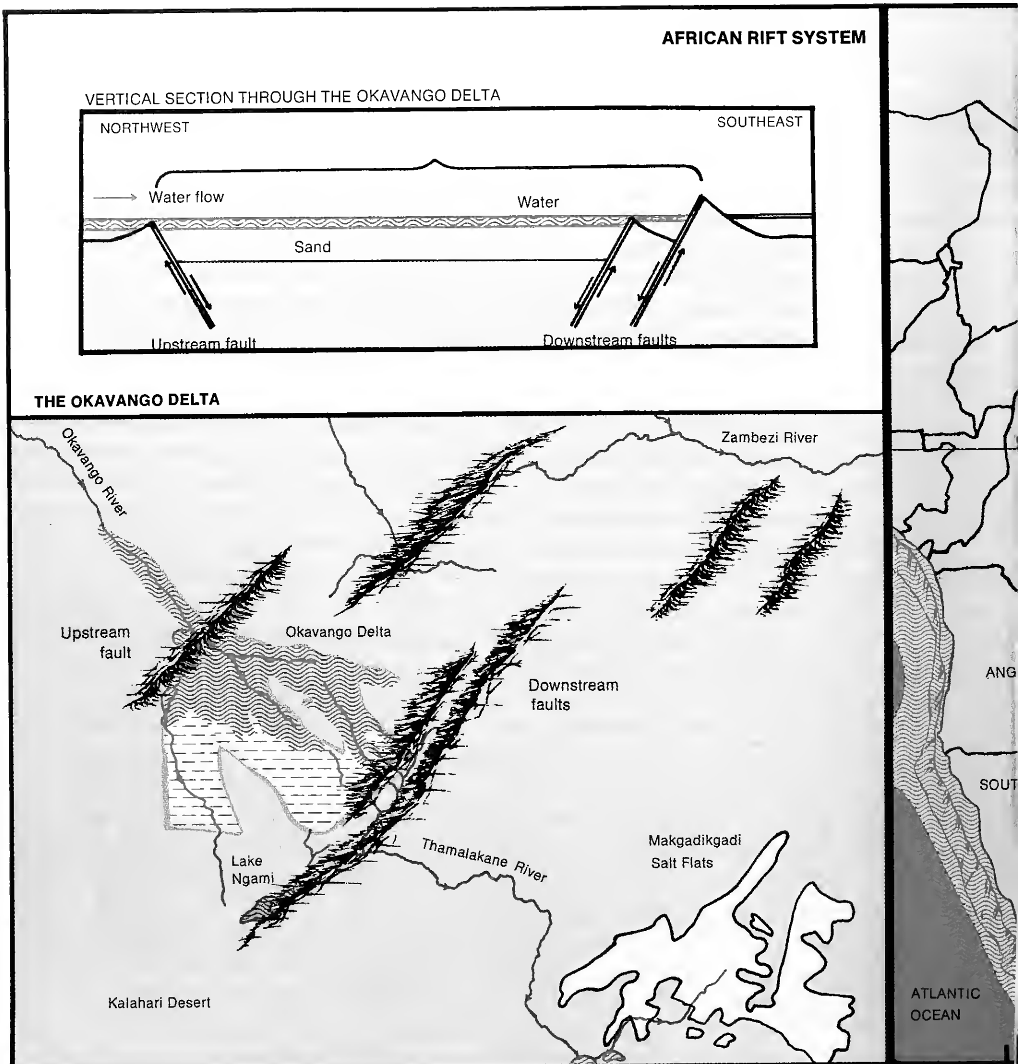
The delta is known as a perched impoundment, that is, its water is at a higher elevation than that of neighboring Lake Ngami and the Makgadikgadi salt flats. This type of impoundment is a natural oddity; in addition the delta has two simultaneously active outlets, instead of one, and these outlets are fed by the same river, which forks in the downstream direction. River forks are almost always on the upstream side.

These are oddities because they are unstable by nature. Channel erosion always favors one outlet over another and works in such a way as to bring water to the lowest possible elevation. In other words, the flow of water is governed by gravity. In a stable configuration, the Okavango River would either still flow to the Indian Ocean or flow entirely into the Makgadikgadi.

Hydrological instabilities of the perched impoundment type can only be maintained so long as local or regional buildups in elevation occur at a faster rate than erosion can tear them down. This requirement is seldom met except in arid environments. High mountain ranges like the Himalayas are sometimes completely transected by powerful rivers only because the river was able to cut a gorge as fast as the mountains rose. But in the flat terrain of the Kalahari, erosion is not rapid. The Okavango Delta lies in a shallow depression formed by upward and downward motion along several geologic faults that extend northeast, perpendicular to the water flow in the delta. The southern side of a fault that crosses the upstream end of the delta is lower than the fault's northern side, thus permitting water to enter the swamps. But a pair of faults, which cross the downstream side of the delta, have been lifted higher than the plane of the delta, thereby creating a 125-mile-long natural earthen dam that has impounded the delta waters. As the Okavango flows over the upstream fault, the river suddenly breaks into a number of channels that fan out to the southeast, where they are blocked by the downstream faults. There the channels reunite to form a single river (the Thamalakane) that flows southwest parallel to the faults and then forks into two branches. One branch passes through a break in the fault scarp, or wall, and flows in an easterly direction to the Makgadikgadi salt flats; the other continues on a southwest course to Lake Ngami. In its slow passage through the delta, the Okavango loses 95 percent of its water through transpiration and evaporation.

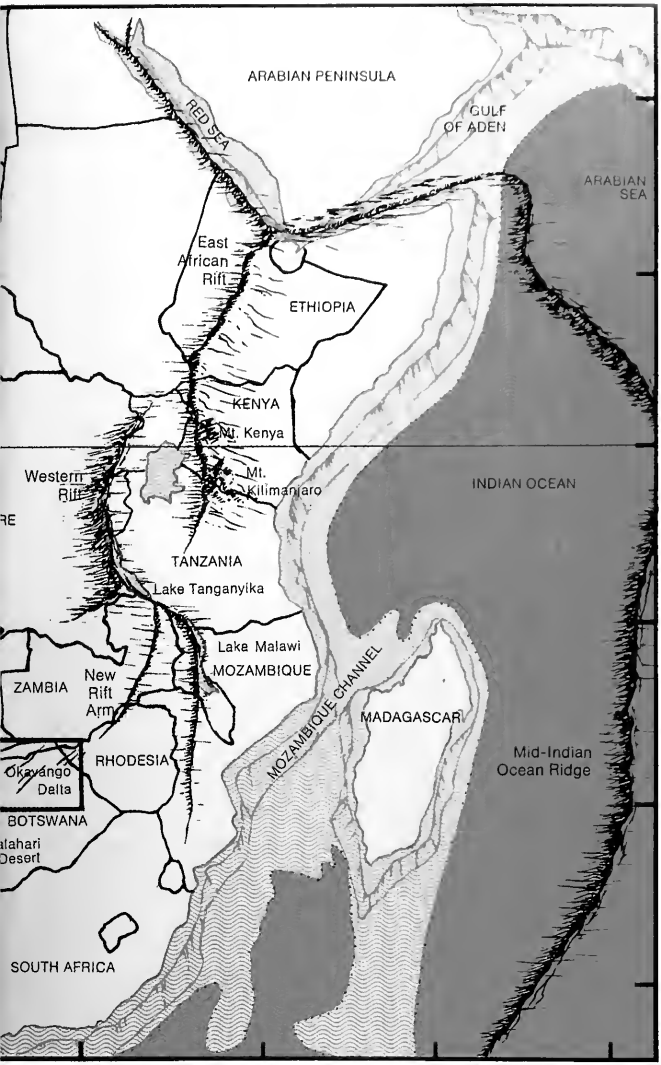
Vertical movement along the upstream and downstream faults, which has taken place within about the last million years, amounts to no more than a few hundred feet, but the frequent occurrence of earthquakes in the region demonstrates that vertical slip is continuing. The topography at the surface of the delta, however, is much less rugged than might be expected from these movements since much of the depression has been filled in by Kalahari sands.

Because the entire region is extremely flat, the flow pattern of the delta is very unstable and has changed radically several times in the last century. Many of these changes have



been caused by heavy papyrus growth, which blocks the stream channels. Other changes have been caused by vertical ground displacements produced by earthquakes.

The first European to visit Lake Ngami was David Livingstone, the famous British missionary-explorer, who reached it by crossing the Kalahari on his initial trip into the African interior in 1849. He described Lake Ngami as being seventy-five miles in circumference. It is less than half that size now, but the old shoreline can still be seen extending far beyond the lake's present fringes. During Livingstone's era, the delta's southernmost channel was its principal outlet and drained directly into Lake Ngami. The lake at that time had its own outlet to the north. In the 1870s the flow from the delta into the lake began to diminish, probably because of papyrus blockage (possibly worsened by seismic activity and faulting), and the lake's outlet was observed to flow in different directions at different times of the year. By the early part of this century the lake's former inlet had become completely blocked, and its former outlet had become its principal inlet. Similarly, a fault-bounded depression just north of the Okavango Delta that received considerable flow in the early part of this century is now almost wholly desiccated. There is even evidence that part of the present Zambezi drainage system once flowed into the Oka-



vango Delta as a result of the damming of the Zambezi by fault movements. It is difficult to assess how many of these flow changes were the direct result of active geologic movements, but it is known that a swarm of major earthquakes in the delta region in 1952 were associated with marked changes in the area's outflow characteristics.

The Okavango Delta exists at present in a broad, gentle depression because the river is dammed behind several developing faults. This depression appears to be the infant stage in the growth of a new rift valley. Although the amount of rifting in the Okavango Delta is minuscule when compared to the great rift valleys of Kenya and Tanzania, where the valley floors have been dropped thousands of feet by motion on the steep fault scarps that bound them, the style of deformation is unmistakably the same. The valleys of Kenya and Tanzania are part of the East African rift system, which extends about 2,500 miles from Ethiopia to Mozambique. The geologic activity in the Okavango region has only recently been recognized as part of this rift system.

The thin outer crust of the earth is composed of a number of large, rigid plates, which float upon the fluid mantle below. These solid, rocky plates are in constant motion with respect to each other, and the interactions between them on their boundaries are responsible for many active geologic phenomena such as earthquakes, mountain building, and volcanoes. Rifting is the process that occurs along plate boundaries wherever two adjacent plates move away from each other, either within continents or existing oceans. If the rifting is well developed, the void created by the diverging plates is filled with upwelling lavas, which solidify to form new sea floor. This process is one of the primary mechanisms of continental drift. True sea-floor spreading and continental drift, however, can only proceed once a rift system spreads entirely through a continent.

The mid-Atlantic ridge is an example of a well-developed rift. It first split the Americas away from Africa and Europe more than 100 million years ago and has allowed them to drift apart at a rate of about 2 centimeters a year. New sea floor has been simultaneously and continuously created by volcanism at the ridge crest. Much younger rifts than that of the Atlantic have just begun to separate still other continents. The rift in the Gulf of California has split Baja California off from the rest of Mexico, and that in the Red Sea is moving the Arabian peninsula away from Africa. Some rifts have subsequently become inactive without ever splitting the continents in which they formed. The Rhine River, for example, flows down a rift valley in western Europe that failed to split the European continent. Thus far, the African rift system has also failed to split that continent.

The most recent active African rifting, which began about 35 million years ago in Ethiopia and spread south through next-door Kenya, peters out in central Tanzania. At its northern end this rift connects with submerged rifts in the Red Sea and the Gulf of Aden, which are separat-

ing the Arabian peninsula from Africa. The Ethiopian, or East African, rift system has produced a trough several miles wide associated with profuse and active volcanism, but this was accomplished by a thinning of the earth's crust rather than an actual rupture, so true continental breakup has not yet occurred. There are active volcanoes inside the rift itself, but Mount Kenya, an extinct volcano, and Mount Kilimanjaro, a dormant one, are also associated with this rift.

To the west, a second rift system is also active. The western rift begins in northern Uganda and extends south, forming valleys that contain such large, deep lakes as Albert, Edward, and Tanganyika. After a jog to the east in southwestern Tanzania, this rift turns south again where its valley is filled by Lake Malawi, also known as Lake Nyasa, and continues southward from Malawi until it dies out in coastal Mozambique. The western rift, like the eastern, also fails to breach the continent. Although the East African, or Ethiopian, rift connects with the Red Sea, the western rift does not nor does it cross the Mozambique Channel and extend to the mid-Indian Ocean ridge, conditions necessary for a complete ridge circuit that would allow for significant continental separation.

It has recently been recognized that yet another arm of the African rift system is beginning to develop. This younger third arm, which was identified by signs of growing rift valleys and the line of earthquakes that follows them, branches off from the main East and West rift systems just west of the northern end of Lake Malawi. From there it runs southwest through Zambia, along the upper gorge of the Zambezi River on the southern Zambia–Rhodesia border, and through the Okavango Delta, which is located at its southern tip. This arm of the African rift system has not yet developed the spectacular form of the older Kenya rift valleys nor is any volcanism associated with it. The recent onset of faulting in the Okavango region suggests that this relatively new rift is moving southward. The Okavango Delta is thus at the tip of a rift that may be spreading throughout the continent.

Africa is a very ancient continent; most of its crust was formed more than two billion years ago in the early Precambrian era, when the thermal and crustal structure of the earth was not sufficiently developed to allow continental drift and sea-floor spreading to occur. Thus the geology of Africa does not consist of the linear deformation belts that mark the traces of old mountain ranges formed at plate boundaries, such as the Appalachians, the Andes, the Alps, and the Himalayas. It is composed, instead, of nearly equidimensional granitic masses, separated by a network of ancient, narrow, highly deformed belts. These belts act as zones of weakness. When rifting occurs in this environment, it moves along the belts, rather than through the granitic masses, following the path of least resistance in much the same way that a tiled floor tends to crack along the mortar rather than across the stronger tiles. That explains in part the sometimes tortuous course the African rifts follow and why they separate into several fingers, each of which appears to advance slowly along the least resistant path through the continent. The Lake Malawi–Mozambique section of the rift system moves along the eastern boundary of a granite mass that underlies most of Rhodesia, while the new Okavango rift arm follows an old deformation belt along the western edge of that mass.

The rifting associated with the initial breakup of continents is evidently much slower than the rate of sea-floor spreading after a continent has been fully breached. Nearly half the Atlantic has accordingly been opened up in the time since the East African rifts began forming. Once one of the arms of a rift system succeeds in completely fracturing a continent, crustal stress disappears and the other arms of the rift become inactive. These inactive, or failed, rifts will then be preserved near the margins of one or both of the newly formed continents. The Connecticut Basin, in which the Connecticut Valley lies—a relict of the rifting of North America from Europe—is one of a series of such basins along the east coast of North America that are instances of failed rift zones.

Interesting as the origin of the Okavango Delta is, its future may prove to be even more so. The region is one of the few game-rich areas of Africa that, aside from the intensive hunting of crocodiles, has remained almost untouched by man, either primitive or civilized. Since gaining its independence from Britain in 1966, Botswana has striven hard to raise its economy above the mere subsistence level that was largely in effect throughout its years as the British High Commission Protectorate of Bechuanaland. The need for development will necessarily bring pressure to utilize the delta for both its land and its water at the expense of the game.

The economy of Botswana is based primarily on cattle, the country's major export. There is thus a continual search for new grazing land. The presence of the tsetse fly makes animal raising in the delta impractical, but as the pest comes under control, cattle posts can be expected to move in, leading inevitably to the eradication of the delta game. Furthermore, the game herds themselves have been recognized as potential carriers of hoof-and-mouth disease, and long fences have consequently been erected out into the Kalahari to prevent animals from migrating into cattle-raising country. Unfortunately, these fences have caused the death of many thousands of weakened game animals by preventing their return to the Okavango Swamps for water during the dry periods.

There is, in addition, pressure from incipient industries to utilize the rare waters of the delta. The need for water has intensified with the discovery of large mineral resources, including diamonds and copper and nickel deposits. Since the geology of Botswana resembles that of South Africa in many respects, the country is likely to prove similarly rich in minerals. There is no question but that the water of the Okavango Delta will be exploited in the future, but it remains to be seen whether this area, almost untouched in the last quarter of the twentieth century, will be used in an ecologically gentle way. □

Great herds of wild game, which could survive nowhere else in the arid land of Botswana, live in the delta and its surrounding marshes.

Peter Johns

Swiss Family Togetherness

by John Friedl

Faced with harsh conditions and a yearly threat of avalanche, Alpine peasants have learned that cooperation means survival

Barren and forbidding surroundings have haunted inhabitants of the Alps since the earliest recorded settlement. Small villages nestled in out-of-the-way corners of high mountain valleys are a monument to human ingenuity, and travelers to the region continually marvel at the unique adaptations that enable the hardy mountain dwellers to eke out a living in such a setting.

One of the most prominent dangers of living in the Alps is avalanche. Each winter tons of snow roar down the mountainsides, wiping out everything in the way. Stream beds formed from melting glaciers or mountain springs act as avalanche lanes, directing the snow and providing it with a clear and unobstructed path. Frequently, the avalanche brings with it a mass of debris, depositing rocks and trees at the bottom of the valley and leaving behind a path of destruction.

In some locations avalanches occur regularly every year, and residents of nearby villages are able to plan around them; in other places they are much less predictable, occurring only once or twice in a century. Avalanches create serious limitations for the Alpine villager. Not only do they destroy houses and agricultural buildings, they also present a danger to life itself. The mere threat of being buried in snow limits mobility in winter, confining villagers for days or weeks on end. When an avalanche does occur, it may close roads and prevent travel for even longer periods of time. The debris brought down by avalanches and rockslides covers agricultural land and must be removed before the land can be used again. Large rocks that cannot be moved inhibit the use of machinery and add to the already difficult task of farming the steep mountain terrain.

The siting of villages, agricultural buildings, and other permanent structures depends upon the location of streams and forests. Numerous streams cut into the slopes of the valley, and buildings must be situated between them, on the valley floor or on the slope. The stream beds restrict the formation of large villages, for even the slope opposite an avalanche can be damaged as a result of the tremendous air pressure created by the rampaging snow.

Villages tend to be located below large patches of forest, which serve

Clustered houses are not only picturesque, they also represent a good use of land in the steep, densely settled, and avalanche-prone valleys of Switzerland.

Swiss National Tourist Office

Adam Woolfitt, Woodfin Camp & Associates

as barriers to the snow. Forestation programs and laws governing the cutting of trees have long been common in the Alps. Villagers can only take deadwood, a practice that not only protects living trees but also clears the forest of avalanche debris. Grazing, too, is regulated to protect buds and young trees from the depredations of animals. In the Lötschental, a Swiss valley on the southern slope of the Bernese Alps, where I lived for a year, such written regulations date back several centuries.

Villagers take other preventive measures as well, such as strictly regulating the harvesting of hayfields located above the village. Because long, uncut grass becomes matted down and is less effective in holding the snow than cut grass, owners of these fields are required to mow the grass in early autumn before the first snowfall.

Houses and agricultural buildings are found in tight clusters, rather than strung out along the length of the valley. This pattern is due in part to careful planning, but the process of trial and error is also important; should a building be destroyed by avalanche, it is unlikely that the owner will rebuild in the same location.

Traditionally, residents of the Alps have divided their landholdings into a number of plots scattered throughout the valley, a pattern known as fragmentation. Helping to maintain this practice in the Lötschental is an inheritance system whereby each child receives an equal portion of the parents' estate, with land parcels divided and subdivided over generations. In the lowlands, fragmentation is a waste of time and energy and an inefficient use of resources. In the Alps, however, such division represents an adaptation to the climate and terrain, as well as to the realities of potential natural disasters.

Despite the harsh terrain and short growing season, agriculture has long been vital to the Swiss mountain dwellers. Gardens, which require the most fertile soil, as well as daily care, are situated near the village, while sheep are taken up to the high grasslands.

Each landowner in the Lötschental holds an average of about nine acres, divided into about fifty parcels of land, including plots scattered throughout the valley. In case of an avalanche, one or two plots of a farmer's land might be covered by snow or rocks. The snow could last until August, and it could take another year of occasional work to clear away the rocks and debris. In the meantime, however, the owner still has the rest of his land to farm. The practice of fragmentation simply spreads out among many families the loss of land and labor from natural disasters.

Another benefit of a divided landholding is found in the way land is used in the Alps. Because of the steep valley slopes, there is a tremendous range in the effects of sunshine, altitude, and climate within a small area. Surrounded by high mountain peaks, the valley floor receives much less sunshine than the higher, more barren slopes and pastures. In the Lötschental, a chain of mountains rising to 13,000 feet borders the valley to the south, shutting out several hours of sunlight each day. During the winter the villages on the valley floor receive barely three hours of sunlight, and on the longest day of summer there are only about thirteen hours of direct sun on the fields.

The weather and terrain dictate a wide variety of land uses and a distinctive agricultural cycle within the extremely short growing season in the mountains. Of the 58 square miles of land in the Lötschental, more than half is unproductive rock and glacier; of the remainder, most is either forest that is owned and carefully protected by the communities or it is found above treeline and used only as summer pasture, since it is too barren to yield even a hay crop. The land available for cultivation is but a small proportion of the total area and must be used carefully if it is to support a relatively dense population.

There are basically four categories of land use in the Lötschental. Gardens, which require the most fertile land, are situated in and around the village, where they can also receive daily attention. Household vegetables, such as lettuce, turnips, beans, and onions, are grown in these gardens. Cultivated fields of potatoes and grain, largely rye, are also found in the village and scattered up the sunny slope above the cluster of houses. Hay is harvested from the meadows that receive the most sunshine, yet are low enough to enjoy a relatively warm temperature. They must also be close to the village or to an agricultural building from which manure can be transported for fertilizer. For all these reasons, the hayfields produce a heavy growth of grass, some of the better ones yielding two crops a year.

The fourth type of land includes the remaining grassland used for grazing animals. During the spring and fall, villagers graze their animals on privately owned meadows that are high, but still below treeline. In summer, however, they take the animals to the higher, communally owned pastures above treeline. Traditionally, women and children brought the animals up to the high meadows in mid-June and stayed with them until October. Every week or so, they made the two- to three-hour walk back to the village, bringing the milk and other dairy products that are a vital source of nutrition for the entire population. Today, however, they remain in the village, making the daily trip up to the pastures by Jeep.

The annual cycle is closely tied in with the use of these different types of land and with the climatic variation according to altitude. The hay harvest lasts several months, starting on the most fertile and sunniest fields, where the grass grows fastest and highest. Once these fields are harvested for the first time in July, the men move up the slope for a couple of weeks, then return to the fields on the southern slope, which receive less sun. Here the grass matures more slowly despite the lower altitude. Finally, the high fields on the northern, sunny side are cut, by which time the lower fields are ready for a second harvest—sometime in late August.

Such a cycle is a major justification for land fragmentation, enabling a farmer to work at a steady pace throughout the summer. If a man's fields are scattered at various altitudes, he will be able to harvest them continually, receiving the maximum yield from each. More importantly,

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while it would be to one person's advantage to own all his fields in the area of greatest fertility, this would be disastrous for the rest of the villagers, since their landholdings would all be of lower quality. Thus, fragmentation not only balances the severe effects of climate and terrain but also offers the best opportunity for the survival of all farmers, given the system of private ownership and independent operation.

There is a high degree of communal spirit and cooperation in Alpine villages, clearly a rational solution to the problems the Alpine peasant faces in coping with his environment. A wide variety of tasks requiring joint participation of some or all residents of the village enables the farmers, who cannot make it alone, to survive through cooperation. Cooperative labor assumes different forms, including recurrent duties such as planting or harvesting and one-time projects that might result from a natural or personal disaster. Small groups within the community engage in cooperative efforts for the good of their membership. And at times the entire community will work together in a communal labor project designed to benefit all.

In valleys where motorized vehicles are not feasible, an individual faces the problem of transporting materials up the steep slopes to the summer pastures. When someone wants to build a hut on the high pasture, to serve as a stall for his cattle and sleeping quarters and a work area for members of his family, he has to carry

Because his house is situated on the edge of town near the path of the predicted avalanche, a villager, along with his furniture, moves in closer to the center.

Dean Loomis, Time-Life

large wooden beams from the forest below. The institution known as *Holztragen*, or "wood carrying," dictates that men, women, and children all help carry the wooden beams and a few other necessary materials up to the pasture. In return for the aid supplied by his fellow villagers, the owner has to pay a nominal fee into the village treasury and supply food and wine for the workers once the job is done. The merriment of the festivities following such a cooperative venture insures that there are no absentees. Constructing the hut itself is the responsibility of the owner, who can usually obtain help from relatives.

Other communal projects follow the agricultural cycle and are also accompanied by celebrations to make the work seem less tedious. In winter, for example, some animals are kept in stalls outside the village; in this way, the villagers are able to collect manure at various altitudes when it is time to fertilize the scattered fields in spring. The daily tasks of milking the cows and cleaning their stalls are tedious, but they represent less work than carrying the manure up from the village in the spring. More time, too, is available for these chores in winter. Furthermore, not all the hay from the high fields must be transported to the village, where storage facilties are inadequate. Rather, only enough hay to feed those animals kept nearby is stored in the village, while the rest can be scattered about the hillside in stalls.

Keeping cattle in stalls on the mountain slope during the winter does create a problem, however, for when a cow has eaten all the hay stored in one small barn and enough manure has been collected, the owner

On the verge of a landslide: An area of unstable rock and snow (1) is poised high above the village of Herbriggen. When it slides, it should follow the natural path made by the ravine (2), thereby missing the houses (3) built along the valley floor to the side of the stream. Trees planted above the village serve as barriers and are strictly protected.

Dean Loomis, Time-Life

must move the animal to another building. But cows cannot walk in the deep snow without sinking. If they are not freed in time, they freeze to death. As a result, a firm path has to be stamped down so that the animals can be moved. Such a task, known as *Vieh verstellen*, or "moving the cattle," requires several men, and when the distance and snow conditions warrant, the farmer may call upon his village's entire male population between the ages of fifteen and sixty, the *Mannstand*.

The construction and maintenance of avalanche barriers above the village, the construction and maintenance of irrigation ditches, and agricultural work in the fields owned by the church or the community all require the cooperation of the entire community. The amount of labor needed to repair and strengthen the avalanche barriers depends upon the damage done the previous winter and upon the continuing horizontal expansion of the villages and the accompanying need to protect more area around the village centers. For many such tasks each household provides one man for the project, but if the labor force is insufficient, every able man and woman helps out.

With the emphasis upon cooperation, social life in the traditional mountain village is organized around the village community. Individualism is played down, for a person alone is powerless against the harsh environment. Instead, the community becomes the focal point for social interaction, and a person's identity is linked to his native village.

To a villager in the Lötschental, for example, members of the other communities in the valley occupy an intermediate position between insider and outsider. The physical and social isolation of the Lötschental has caused a great deal of inbreeding over the centuries. Every native resident has many relatives in the adjacent villages and through them, a number of social contacts as well.

On the other hand, residents of each village share a wide variety of derogatory jokes, feelings of superiority, and popular misconceptions about the residents of the other villages. Natives of one village are said to resemble the wooden masks, known as *Tschäggättä*, worn in the local Mardi Gras festival. Those from a second village are supposedly distinguished by their rapid, almost unintelligible speech, while a third village is characterized by its allegedly gluttonous population.

This particular combination of terrain, climate, and altitude, coupled with the unique history of the valley, is important in creating village solidarity in the Lötschental. There has always been a high rate of intravillage marriage. Much of the courting takes place during the winter when the agricultural schedule is not so demanding and young people have more time to themselves; at that time, however, avalanche danger restricts travel, no doubt enhancing the desirability of the girl next door. The high rate of inbreeding, in turn, affects the feelings of village solidarity, not only through family interaction but also through inheritance practices that pass on land in the village to future residents of that village, thereby excluding others.

Recently, after a series of heavy snows followed by warm weather and some rain, a serious avalanche occurred in the village where I lived, leaving more than thirty feet of snow on the road just outside the village, knocking down electric lines, and completely demolishing a vacation chalet. Because avalanche conditions persisted for some time, work to repair the damage did not begin until the following week, and it took more than three weeks to dig a tunnel through the snow to allow normal traffic in and out of the village. Electricity was restored a few days after the avalanche, but mail had to be flown in by helicopter and factory workers were flown out to their jobs outside the valley.

During the three weeks that the village was closed off, I witnessed a remarkable change in atmosphere. People grew closer together and the feeling of community spirit increased noticeably. At one point when there was the threat of a second avalanche, people living at the edge of the village moved in with relatives who lived closer to the center, preferably those living next to the church, which has been standing since the sixteenth century. Until electricity was restored, villagers could not run their oil burners and had to depend on small space heaters. Since propane gas, used to fuel such heaters, was in short supply, several families moved in together. Participation in long evening card games in the heated taverns, sharing of food and other resources, and the congenial acts toward me, an outsider, finally enabled me to understand the feelings that tied the residents of the village together in a way that I had not previously been able to comprehend.

Once made of wood, at right, or stone (an efficient way of clearing the rocks left by previous slides), avalanche barriers are now made of aluminum, which is light, sturdy, and weatherproof.

Swiss National Tourist Office

Through this experience I learned how time and again, when people are faced with natural disasters, they turn to the only source of support upon which they can consistently rely—their fellow villagers. The intensity of village cooperation created by the environment, coupled with the magnitude of the obstacles to be overcome and the vagaries of nature to be endured, has created a rare form of village—where cooperation is the rule rather than the exception. □

The seventeenth-century church at Oberwald, built into the slope of the mountain, is prow-shaped at one end to deflect the path of the rampaging snow.

Swiss National Tourist Office

Plant-loving Bats, Bat-loving Plants

by Donna J. Howell

For food and sex,
two unlikely partners
have evolved together

Bees, butterflies, and hummingbirds are familiar nectar feeders and pollinators of flowers, and the flowers they serve possess elaborate devices to deliver their nectar and pollen. Flowers with bright red blossoms and tubular corollas, for example, are often pollinated by hummingbirds. The birds are attracted to bright colors, and their long beaks are suited for the extraction of nectar at the bottom of deep, tubelike corollas. In this example of a classic symbiotic relationship, the birds obtain nectar as food and the plants are pollinated by the feeding birds as they travel from flower to flower.

A similar relationship between certain plants and pollinators is not as well known. In tropical and subtropical countries, and extending into the southwestern United States, nectar-feeding bats are common pollinators of a wide variety of plants. The relationship of these partners is called chiropterophily—literally, "bat-loving" and figuratively used to describe the characteristics of both bats and plants. To the bat biologist or pollination ecologist, the characteristics of the plants and their bat pollinators stand out as strongly as do those of the hummingbird pollination system.

My work in the tropics and search of the literature reveals 130 genera of chiropterophilous plants. These are scattered unevenly through 40 plant families with the *Bombax, Bignonia,* legumes, and cactus families having the greatest share. Many tropical lumber trees are bat pollinated. So, too, are the giant saguaro cactus and the century plant, a paniculate *Agave.* Some chiropterophilous paniculate agaves from south of the border are the sources of tequila and sisal. A number of other commercial products also owe their existence, in part, to bat pollination. The calabash tree, *Crescentia cujete,* whose gourd-like fruits provide dishes and utensils in Central America, is pollinated by bats. The silk-cotton tree, *Ceiba pentandra,* whose down-filled seedpods are set from bat-pollinated flowers, is the source of a filler called kapok, commonly used in sleeping bags, life jackets, and cushions. Other bat-pollinated tree species are *Ochroma lagopus,* from which balsa wood is obtained, and *Capparis,* the source of capers.

Since the syndrome of chiropterophily involves different families of bats in the Old and New Worlds, and since bat-pollinated flowers have evolved in a number of plant families, this symbiotic partnership probably arose independently a number of times during the last fifty million years. For example, in the Old World tropics, some fruit bats, or flying foxes, feed on nectar and pollinate flowers. These bats are anatomically distinct from nectar-feeding bats of the New World. In the American tropics, several subfamilies of the leaf-nosed bats fill the same ecological niche. These two groups of bats represent parallel evolution, rather than the sharing of an immediate common ancestor; the similarity of their life-styles is reflected in similar morphology. The same is true of the bat-loving plants; although they may be unrelated, having similar pollinators has helped to mold their features into common patterns.

Both groups of nectar-feeding bats have relatively large eyes. Vision is of critical importance to the Old World species since they have no sonar. I have recently demonstrated the degradation of sonar acuity in the New World nectar-feeding bats. These species may emit only one-hundredth of the sound energy used by their insect-feeding relatives.

Both Old World and New World nectar-feeding bats have large septate nasal cavities and vomeronasal organs, indicating a good olfactory sense. Both groups possess long muzzles and weak teeth. In many species, the number of incisors and molars is reduced. The gap left by the absence of lower incisors in the more specialized forms, together with a

Numerous florets in a "shaving brush" arrangement aid in the pollination of some agaves. The bat Leptonycteris sanborni *is lathered with pollen as it feeds on nectar.*

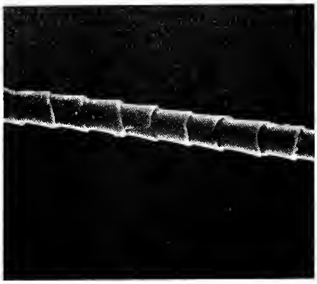
groove in the lower lip, facilitates the movement of an extremely long, extensile tongue.

The characteristics of chiropterophilous flowers reflect their dependence upon bats for reproduction. Such flowers open at night and are white or light in color. They have a peculiar musky, or "batty," odor. On moonlit nights, bat-pollinated flowers stand out almost as if they were fluorescent. The odor, which may be noticeable only after dark, often forms an aura that surrounds the tree. The odoriferous substance has been found to contain butyric acid, since bat body musk also contains butyric acid, it has been hypothesized that the odor that attracts bats to bats also attracts bats to flowers.

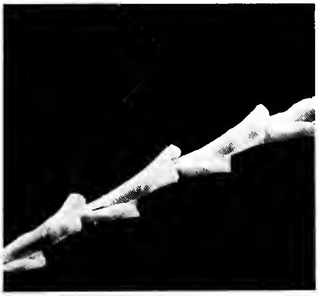
Bat-pollinated plants have a number of peculiar growth forms, all of which accomplish the end of spatially separating the flowers from the rest of the plant. This separation, combined with noticeable paleness and a batty odor, provides a very prominent target to a night-flying bat, which orients by sight and smell a bat ill-suited, sonarwise, to deal with a clutter of vegetation

The conspicuous placement of chiropterophilous flowers is accomplished in several ways. One of the most dramatic occurs in the century plant, whose flowers are presented on "serving tray" panicles located on the ends of branches that emanate from a central stalk. The stalk itself

John A. L. Cooke, Oxford Scientific Films



Donna J. Howell



Scanning electron micrographs (at × 550 magnification) reveal an adaptation of nectar-feeding bats. The hair scales of an insectivorous bat (top) lie flat and smooth against the hair shaft. Angled away from the shaft, the hair scales of a nectar-feeding bat scoop up and trap pollen grains when the bat visits a flower.

rises twenty or more feet above the rosette of swordlike leaves that constitutes the main body of the plant.

Another adaptation for separating flowers from foliage, thereby providing easy access for the pollinating bats, is called flagelliflory. The flowers of a tree are borne on long, whiplike branches that protrude above the main canopy. Penduliflory is an upside-down version of the same thing. In this adaptation, flowers hang down below the canopy on a long rachis, or streamer. This strategy is commonly seen in chiropterophilous vines, which grow quickly from the dark forest floor up to the sunny jungle canopy by climbing on a host tree for the light they need; then produce night-blooming flowers on sixty-foot-long streamers that droop down through the subcanopy where bats can easily find and pollinate the blossoms. In cauliflory, a somewhat different means of accomplishing the same end, the flowers develop directly from the trunk of a tree or from thicker parts of the branches. When fruits set from these oddly placed flowers, the effect is of balls glued directly to the tree.

In combination with such branching patterns, many bat-pollinated plants shed their leaves at the time of flowering. This also serves to present the bats with easily identifiable, accessible targets.

Bat-pollinated flowers also have certain shapes that help to transmit pollen to the visiting bat. There are two general types. One is vessel shaped with exserted anthers; the bat must thrust its head through the pollen-producing anthers into the corolla to reach nectar at the bottom. In so doing it gets coated with pollen. The second type is a filamentous ball, sort of a "shaving brush," made up of numerous florets or of one flower with numerous, long anthers. Often nectar collects in a groove near the stem end of the flower. The bat grasps the brush in order to reach around to the stem end for nectar and in the process gets its chest covered with pollen grains.

In addition to these main types there are other pollination mechanisms; for example, some flowers release spring-loaded anthers in response to a bat's weight—showering the bat with pollen.

Besides the morphological coadaptations of individual bat and plant species to one another, there are other interactions that mark chiropterophilous communities. A positive correlation exists between the range of bat-pollinated flowers as a group and that of nectar-feeding bats. This suggests that these bats might be limited in their range by lack of appropriate food or that certain plants might be limited in their distribution by the absence of proper pollinators.

There is also a high degree of temporal synchronicity between the partners. Some nectar-feeding bats, such as *Leptonycteris*, migrate. They are in Arizona in late May through August, feeding on saguaros and then agaves. Moving southward, they feed on later blooming agaves and winter on a lush complex of flowering trees in central Mexico. In early spring, they feed on early blooming columnar cactus, moving northward until they again reach Arizona. These migratory movements and flowering periods are examples of interrelated characteristics that have fostered geographic and temporal coadaptations of bats and plants.

The relationship of chiropterophilous plants with bats is, to a high degree, exclusive and obligatory. Nocturnal blooming narrows the field of potential pollinators to moths and bats. Moths seem to prefer more fragrant flowers to the relatively malodorous bat-pollinated blossoms. Even those chiropterophilous flowers that appear to remain open during the day may be ecologically closed to other potential pollinators because pollen and nectar may be available only at night.

I was first attracted to the study of this bat–plant syndrome by its inherent physiological problems. The bats, being small, warm-blooded mammals that fly and hover (a metabolically expensive form of flight), require tremendous energy input to keep up with their metabolic demands. Nectar-feeding bats do not engage in the energy-saving daily torpor common in temperate-zone bats. Neither do they hibernate; they metabolize at full speed all year long. Their heart rates in flight may exceed 500 beats a minute. Nectar-feeding bats must have a hard time playing butterfly.

Bat-pollinated flowers do provide their symbionts with copious quantities of highly caloric nectar. While setting up experimental diets for a laboratory colony of nectar-feeding bats, I cut and drained panicles of an agave in the field; I would remove one-fourth to one-half cup of nectar from a single panicle and often received a shower while cutting the higher branches.

This nectar has a sugar content of 17 to 20 percent, and the bats have a most efficient way of taking in a lot of nectar in a very short amount of time, thus optimizing their energy budget. The tip of the bat's long thin tongue has a superabundance of fleshy bristles that increase the surface area to an amazing 200 square

millimeters. Hummingbirds and other nectar-feeding birds and insects have similar nectar "mops."

What intrigued me most was the notion, supported by some scientific literature, that the bats feed on nectar only. Most nectar contains no protein and animals cannot synthesize it from sugar water. No long-lived animal can maintain itself on a pure carbohydrate diet; it must have an external source of protein (amino acids or nitrogen) for the production of cells and tissue. You cannot make a bat out of sugar and water.

Since 1968, I have studied a subfamily of nectar-feeding bats, the Glossophaginae. These bats range from Arizona and Texas through Mexico into South America. Even though the nine genera in the subfamily share, to some extent, the general characteristics of pollinating bats, they are not equally committed to feeding on nectar. Some eat moths during half the year, satisfying their protein demands from that source; others are full-time flower visitors, never eating bugs save an occasional thrip lapped up with the nectar. The degree to which each bat species demonstrates a long snout, weak dentition, and poor sonar depends on its constancy to nectar feeding. Yet even the nectar-feeding bats that snack on insects during the wet season, when bat-pollinated flowers do not bloom, have a potential protein-deficiency problem when they switch over to nectar; bats that are exclusively flower visitors have the problem all year.

I concentrated my research on the genus *Leptonycteris*, the long-nosed bat, which is an obligate nectar feeder. I examined guano or stomachs from hundreds of individuals collected throughout the year in all parts of their range. Only occasionally did I find an insect fragment in the material I examined. These bits could be identified as thrips or certain small bees and beetles that frequent the blossoms of chiropterophilous plants. I guessed that these were incidentally ingested with the nectar. Work I did several years later confirmed that these insects could not be captured on the wing: the sonar acuity and dentition of long-nosed bats do not suit them for actively hunting insects.

What the bats were eating was nectar and pollen. Pollen is perhaps the most obvious protein source since other nectar-feeding animals depend on it (bees and heliconiid butterflies), but a number of questions remained to be answered before its usefulness to bats could be assumed. Pollen in general can have protein or amino acid content roughly comparable to beans (15 to 20 percent). Pollen grains, however, have a tremendously resistant outer shell, or exine. The resistant shell allows pollen to remain intact in the earth for millions of years, providing a fine paleoecological tool, but because of the nature of the exine, scientists have had difficulty investigating the actual cellular contents inside pollen grains. Many kinds of pollen will wear out the bearings of electric grinders before they are broken, and pollen can withstand boiling in hydrofluoric acid (which etches glass).

The problem of how to get around

Donna J. Howell

Nectar-feeding bats, which have poor sonar but good sight, easily locate these agave flowers, which are borne on a tall stalk high above the plant's spiny leaves.

Donna J Howell

this shell and gain access to the nutritious material within is a very real one for the bats. But the Glossophaginae, and presumably the Old World pollinating bats, have several mechanisms to cope with this problem.

Pollen will begin to germinate in a warm sugar solution, which is usually present in the stomach of a nectar-feeding bat. The cellular contents will extrude through pores in the exine when in such a liquid medium. At this point the bat must be able to degrade, or break down, the pollen proteins into smaller units, or amino acids, in order to construct bat proteins.

When an allergist wishes to make an extract of pollen proteins for allergy tests, he soaks the grains in weak solutions of hydrochloric acid and/or urea—two chemicals that can degrade pollen proteins. As in most mammals, bats' gastrointestinal tracts secrete hydrochloric acid. In long-nosed bats, the glands that produce this protein-degrading chemical are so numerous as to almost exclude other types of glands found in mammal intestines. Also, long-nosed bats exhibit the behavior of drinking some of their own urine. This activity is distinctly different from cleaning of the genitalia. A drop of urine at a time is excreted and picked up with the long tongue, a behavior that has been observed while the bats were feeding on pollen in flight. The resultant nectar-hydrochloric acid-urine solution in the bats' stomachs enables them to gain access to, and begin the breakdown of, pollen protein.

Further experiments confirmed that bat-pollinated flowers are able to supply a sufficient amount of protein and amino acids to their pollinators—a crucial factor in the survival of an en-

To reach the nectar at the [illegible] of an organ pipe cactus flower, a Leptonycteris bat thrusts its [illegible] into the tubular corolla (left). After lapping up a quantity of the sweet fluid with its long, bristly tongue (left), the bat will fly off with a coating of pollen on its face and neck. Some of the pollen grains will be consumed in flight; others will be transferred to the next flower the bat visits, thereby pollinating the plant.

dothermic animal with a longevity of up to ten years. In general, adult mammals require that 10 percent of the digestible material in their diet be protein. In young, growing mammals the figure approaches 20 percent. Specifically, long-nosed bats need 140 to 170 milligrams of protein or amino acids daily. In order to determine whether chiropterophilous plants could provide this, I collected pollen from many species and ran tests for amino acid content. The pollen proved to be extremely rich: pollen from saguaro cactus flowers contains 20 percent protein; that of paniculate agaves, 43 percent.

Even more interesting, the pollen of flowers adapted for bat pollination contains, on the average, two times more protein than the pollen of closely related plants that are pollinated by wind or insects. For example, the prickly pear and the barrel cactus, which are insect-pollinated, contain only 9 percent and 10 percent protein compared to the saguaro's 20 percent. Pollen from two species of spicate agaves, *Agave schottii* and *A. parviflora*, which are bumblebee pollinated, shows 8 percent and 16 percent compared to the 43 percent pollen protein content of bat-pollinated agave pollen. This was one hint that the plants in this symbiosis evolved biochemically, as well as morphologically, to attract bat pollinators.

Long-nosed bats that were collected when returning to their roosts at dawn had stomach contents that weighed four grams. Three grams of this was nectar and one gram protein. This mass may not represent a total night's food intake; we believe that

The flowers of saguaro and organ-pipe cactus grow directly on the trunks or branches of the plants, making them conspicuous to nectar-feeding bats.

Donna J. Howell

bats feed at least twice, stopping to digest in the middle of the night. Figuring conservatively, if a long-nosed bat ingests only one gram of pollen per night and this pollen contains 20 to 40 percent protein, the bat will get 200 to 400 milligrams of protein, which more than covers its needs.

Simply ingesting the proper quantity of protein, however, is not sufficient to support life; an animal must ingest the right kinds in the right proportion to replace what it has used. While doing chemical analyses of chiropterophilous flower pollens, I discovered that they contain a full complement of essential amino acids. Furthermore, they have a remarkable abundance of two amino acids that have no known role in the plant's own reproductive biology. These amino acids, proline and tyrosine, may supply specific needs of the bats. The first is crucial in building connective tissue, and bats, which have extensive wing and tail membrane surfaces, are high in connective tissue. The second amino acid is a growth stimulant to young mammals; it concentrates in the mother's milk. Tyrosine is also a component of protein-splitting enzymes. The plants that contain the maximum amounts of tyrosine are fed upon by the bats during pregnancy and lactation, times of high protein demands.

Since pollen plays such an important role in the diet of nectar-feeding bats, we might suspect that they have certain adaptations to aid in their pollen gathering, just as the high surface area tongue affords increased nectar pickup.

I had noticed that hairs in the neck region of the glossophagine bats did not lie flat in any one direction as does most mammal fur. Rather, the hairs stand out like bristles on a bottle brush. The scanning electron microscope revealed further unique features of hairs of pollinating bats. Both Old World and New World bats involved in pollination syndromes have hairs made up of small scales that stand out at wide angles to the main hair shaft. These hair scales serve as pollen scoops, and the thickness and upright position of the hairs on the body help to trap millions of pollen grains. The bat hair scalation may be adaptive to the plants in the partnership since the more pollen an agent carries and retains over a distance, the more likely that flowers on subsequent plants will receive some. For the bats, picking up a heavy coating of pollen is important because pollen is their only reliable protein source. Hairs of bats not associated with flowers, such as the vampire and insectivorous bats, have scales that lie flat and smooth against the shaft.

The bats often come away from flowers golden yellow in color, having picked up abundant pollen on their fur. While in flight or resting, they groom the pollen from the fur with their feet, licking the claws after every combing bout. It is in this manner that long-nosed bats ingest a gram or more of pollen per night.

To determine how and why chiropterophily originated is difficult. Organisms may become involved in such cooperative interactions only if they have been a part of one another's environment for a long time. The pattern develops in a reciprocal step-by-step fashion over millions of years. But an analysis of the advantages accruing to each partner in return for the energy expended gives us some

insight into this evolutionary drama.

To attract bats, plants must produce copious quantities of high caloric nectar, which is of no use to the plants' own immediate biology. They must also produce a higher quantity and quality of pollen than is needed for their own reproduction. This energy cost to the plants should not be viewed just in terms of how much pollen and nectar they must produce; the ratio of energy invested to benefits gained (fertile seeds set) is the important criterion of a successful reproductive strategy. Wind-pollinated flowers produce fantastic numbers of pollen grains, but only a very few ever reach another flower of the same species. Using a predictable agent of pollen dispersal, such as an animal that is a relatively constant visitor, minimizes waste of pollen and maximizes appropriate transfer. This should lessen the energy drain on the plant, which can now get by with less pollen. But why a bat?

Given that plants compete for resources in their environment, finding new resources may allow a species temporary escape from competition and a chance to exploit a new niche. Pollinators may be viewed as resources in the plants' environment. In this light, there are multiple advantages to having bats as pollinators, as they may allow plants to escape competition both in space and time.

With a finite number of hummingbirds, for example, plants may be in competition for the services of the birds. Two roads are then open to the plants: "getting better" or "getting out." Those plants that "get better" become more attractive to hummingbirds, perhaps by the evolution of brighter flowers or sweeter nectar. Those plants that "get out" carry the baggage of their previous life-style and must find a pollen vector that will accept most of those characteristics. Hummingbird flowers have some of the features attractive to bats: they are sturdy, they offer a good quantity of nectar, their anthers tend to protrude, and their bell shape is suitable. A change to nocturnal blooming, the lightening of color, or the addition of a musky odor might be a relatively minor evolutionary price to pay for an escape from competition.

The shift to nocturnal blooming and use of nocturnal pollinators possibly provided some plants an escape from crowded diurnal systems. This bridging-over may have started from insect-pollinated systems as well as from bird pollination. Bat-pollinated plants today have close relatives in insect and bird syndromes.

Besides the escape in the time dimension that bats provide, there are at least two other advantages for the plant. Bats are warm-blooded; because they carry their own heat source, they can remain active in cooler environments than can insects. Having bats as pollinators might allow certain plants to expand their ranges into cooler latitudes or higher altitudes where competition for a number of resources might be less severe. In a sense, having bats as pollinators might allow plants to invade and radiate into an empty niche.

Bats may cover tens of miles in a night's foraging. For plants to take advantage of the evolutionary flexibility and vigor that accompanies outcrossing, they must compensate for their own lack of mobility. They must interact with an agent that can transfer gametes from one member of the population to another. Tropical plant species are often widely dispersed. Walking through a rain forest, one sees hundreds of plant species but seldom sees two of the same kind in proximity. This scattering of individuals in the population may be a strategy to minimize predation on the plant population. But being hyperdispersed, the plants require a highly mobile pollinator that can effect the union of sex cells. Bats are admirably suited to this task.

Of course, this one-sided view of the evolutionary chess game assumes there were fully evolved nectar-feeding bats ready and waiting for the plants, which was not the case. It must be understood that mutualistic systems evolve as single biotic units. We have simply decided, for the sake of analysis, to move the chess pieces one team at a time.

Some of the advantages to the nectar-feeding bats are direct analogues. Bridging over from one type of feeding to another may have been stimulated by competition among bats. Through the ages, certain bats in competition for fruit might have found that straggling flowers that had not yet set fruit had a similar smell and provided a tasty snack. Other kinds of bats that competed for insect food might have come to rely on flowers as gathering places for insects and gradually made the shift in diet.

The transitions took millions of years, with some bats coming to rely more and more on the food from flowers and less on insects or fruits. The process is ongoing; from our tiny time perspective we see the transition reflected in the dietary continuum that exists in the Glossophaginae today. Some bats in this subfamily rely on insects part-time; other relatives of nectar-feeding bats eat fruit but don't turn down nectar, and possibly pollen, when it is abundant.

The end result of these reciprocal changes is speciation: new kinds of bats, new kinds of plants. The isolation or integrity of a plant species may depend totally on the behavior of its pollinator. Organisms evolve new features in response to some change in their environment and, in turn, create a changed environment for other organisms.

Robert Ricklefs, in a recent ecology text, says, "Evolution is self-accelerating in that environmental complexity produced by life forms creates additional opportunity for the evolution of new forms." If we believe this, we must see that mutualistic interactions play an important role in the development of most organisms, populations, and communities. Ecology texts, while dwelling on competition and predator–prey dynamics, dismiss mutualism as a phenomenon whose importance in populations in general is small. There is now growing evidence that interactions such as those between plants and pollinators might generate and maintain certain aspects of community structure. Pollinators, for instance, may determine the diversity and phenology of plant communities.

There has also been a tendency in biology to concentrate on the responses of one kind of organism. This ignores the synthetic approach demanded by Ricklefs's statement. During the last decade, however, zoologists and botanists have begun to converge on points of common interest in pollination syndromes, as well as other phenomena. We are beginning to realize that organisms do not evolve in a vacuum. □

Reef Fish Lottery

by Peter F. Sale

Contrary to most ecological principles, chance, not competition, seems to regulate some fish distribution on the Great Barrier Reef

Coral reefs, as anyone fortunate enough to have dived among them knows, abound with a tremendous variety of life. Particularly conspicuous are the reef fish, whose forms, colors, and activities bring them instantly to attention. No other environment can support such a diversity of fish species.

At the northern limit of reef development, the Hawaiian reefs, thousands of miles from other reefs, support 400 species of inshore fish. At the southern limit of the Great Barrier Reef, the Capricorn Islands group, which forms the final link in a discontinuous. chain of reefs extending 2,000 miles along Australia's coast, supports more than 800 species of fish. At the northern end of the Great Barrier Reef, about 2,000 species of fish occur. By contrast only about 350 species of inshore fish live off the coast of California where there are no reef formations.

Just as reef systems support many hundreds of fish species, small areas within reefs also contain a surprisingly large number of species. C. Lavett Smith of The American Museum of Natural History has reported that in the Bahamas it is not unusual to collect 70 or 80 species from a single coral patch three yards in diameter. Frank Talbot of the Australian Museum has collected more than 150 species of fish from similar areas in the Capricorns.

This high diversity of reef fish in small areas has not been easy to explain. Two questions present themselves to the biologist: How have such large numbers of fish species evolved on coral reefs when similar numbers have not evolved in other environments? And by what mechanisms have the species present on coral reefs managed to coexist? In an effort to answer the latter question, I spent the past three years studying eight successfully coexisting species of fish on Heron Reef in the Capricorn group of Great Barrier Reef.

Ecologists have generally accepted that species that are similar to each other in their ecological requirements will not be able to coexist indefinitely in a stable environment. As the populations of two similar species grow, they will ultimately compete with each other for the resources, such as food and living sites, that both require. In this competition, one species will inevitably be more efficient than the other. Over a period of time, the more efficient species, consistently obtaining more than its share of resources, will prosper at the expense of its less efficient competitor. The latter must evolve new ecological requirements or it will become extinct wherever the more efficient species occurs. This result will occur so long as the environment is stable enough for one species to be consistently more efficient, and so long as the less efficient species, once eliminated, cannot reinvade from another area. This is called the principle of competitive exclusion, also known as Gause's principle.

By the principle of competitive exclusion, reef fish occurring together should show measurable differences in their ecological requirements. Since there are so many species of reef fish present at any one site, we might expect that, in order for them to show differences in ecological requirements, they will also tend to be specialized animals. When the requirements of reef fish are examined, however, this is not the case. There are certainly a few highly specialized forms, but most reef fish appear no less generalized, both in their food and habitat requirements, than fish from temperate areas. Perhaps even more surprising is that these fish can be grouped into guilds—groups of species whose requirements are extremely similar—and several species belonging to a guild will often inhabit the same part of a reef. Such coexistence appears to contradict the principle of competitive exclusion and makes the question of how reef fish coexist a significant one.

The eight species that I am studying are all damselfish of the family Pomacentridae and all belong to the same guild. They are territorial species and establish their individual areas only on dead coral rubble that is usually covered with a fine turf of filamentous algae, their principal diet. Each fish obtains all its food from within its own territory.

Damselfish produce demersal eggs, which are deposited in a nest within the male parent's territory, and the male cares for the eggs. After several days, the eggs hatch into minute larvae about one-sixteenth of an inch long. These lead a planktonic existence before returning to the reef as half-inch-long juveniles. We are woefully ignorant about the larval ecology of reef fish, but judging by the increase in size that occurs between hatching and return to the reef, damselfish must spend at least a week (more probably a month) in the plankton. During this time they may be carried many miles from their hatching sites before seeing a reef again. On the trip most of them are probably eaten or die from other causes.

Once they have returned to the reef

F. Sale

as juveniles, the fish begin to maintain territories and continue to do so throughout their adult lives. The usually contiguous territories are less than one foot in diameter for juvenile fish and from seven to ten feet in diameter for the largest adults, which are four to six inches long.

As a young fish grows it must add to its territory at the expense of some of its neighbors or be lost from the area. In such competition each fish constantly and vigorously defends its own territory from entry by various other fish species belonging to the guild. Only when spawning occurs is territorial defense relaxed, and then for only a few minutes.

This guild has proved particularly suitable for study. The fish move about sufficiently, are all diurnally active and of a size readily observed by a diver. Perhaps most important is their defense of territory. In being interspecifically territorial, these species have ritualized any competition for resources that occurs among them into a competition for living space. To determine the similarity of their ecological requirements, it is only necessary to consider the similarity of their spatial requirements.

My research methods can be likened to that of an "underwater bird watcher" since it is possible for a diver with suitable equipment to remain motionless in the water and observe the activity of fish several yards away. I have selected several patches of suitable habitat in which to follow the activities of these fish, and for the past three years, I have visited these sites every four months.

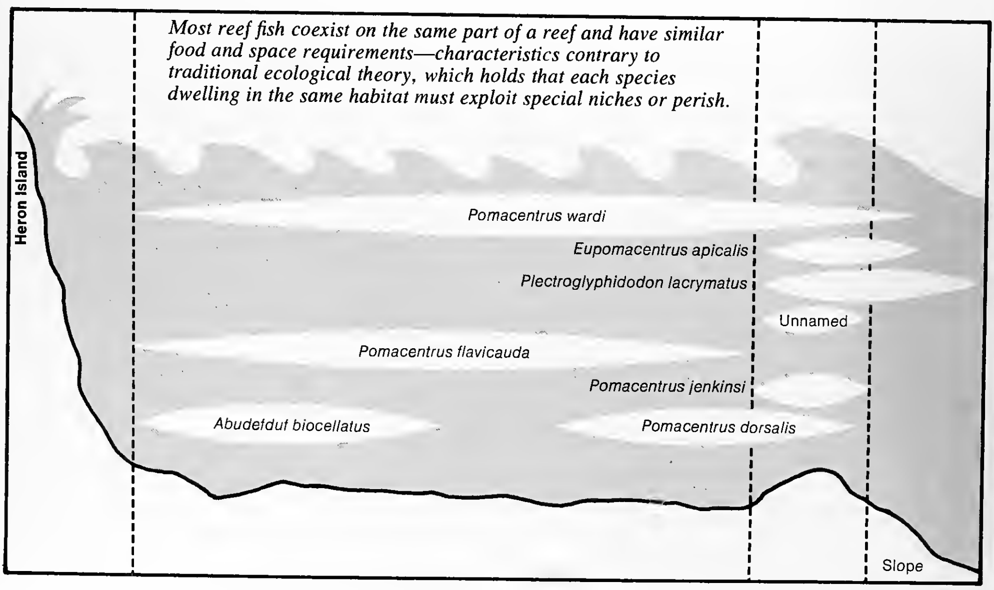
By following the movements of each fish as it actively patrols the borders of its territory, I have been able to create maps showing the ownership of space in these rubble patches. Comparison of maps made on successive visits to a rubble patch provides information on mortality or emigration, numbers of additional resident fish, changes in the sites used by particular individuals, and changes in the ownership of sites. The consistency of territoriality can be determined by the latter finding. In some parts of the reef, I have removed resident fish and have observed subsequent events over varying lengths of time.

The distribution of the eight species across Heron Reef shows some spatial separation; all eight species do not occur over the same parts of the reef. To this extent the fish are showing the specialization and differentiation of ecological requirements that the principle of competitive exclusion would predict. Nevertheless, there is no place on the reef where a patch of rubble could not be occupied by at least three species of the guild. On the reef crest, six species occur.

My most detailed information concerns the coexistence of *Eupomacentrus (Pomacentrus) apicalis, Pomacentrus wardi*, and *Plectroglyphidodon (Abudefduf) lacrymatus.* These species occur together on the upper reef slope before it drops off into deeper water. While *P. wardi* occurs elsewhere, the others are limited to this part of the reef. My observations throughout Heron Reef indicate that the ability of the three species to coexist is representative of guild members on other parts of the reef.

The three species inhabiting the upper reef slope have remarkably similar requirements for resources. My research suggests that all three species are in competition for space in rubble patches; that in the face of this competition, all are quite successful in holding on to space in rubble patches (although there are slight differences among them in this ability); and that their requirements for space are, so far as can be determined, identical.

That these species compete for space is demonstrated by the occupation, by one fish or another, of all the apparently suitable rubble in a given



Most reef fish coexist on the same part of a reef and have similar food and space requirements—characteristics contrary to traditional ecological theory, which holds that each species dwelling in the same habitat must exploit special niches or perish.

area, and the total amount of space used is constant except during the early winter when it declines slightly. Also, when one fish disappears or dies, the space it vacates is rapidly refilled by another fish.

In numerous instances I have observed young individuals of these species successfully maintaining a space while surrounded by adults larger than themselves. They are able to do this by fleeing into small crevices within their territories whenever a large fish attacks. The larger neighbors are thus not able to drive the juveniles away. By the time a young fish has grown too large to enter small crevices to escape from its neighbors, it is also large enough to defend its territory.

Pomacentrus wardi, smaller than the other two species inhabiting the reef slope, is only slightly less successful at holding space on the rubble patches. It also shows slightly greater mortality and emigration rates. This species, however, produces proportionally more new recruits to rubble patches than the other species. This presumably is because *P. wardi* is widely spread over the reef, occurring at a density of about one fish per two square yards and accounting for 50 to 90 percent of guild members sighted on any transect. *P. wardi* is obviously capable of producing a large number of larvae. The greater rate of arrival of new juveniles of *P. wardi* on rubble patches is sufficient to balance its higher rate of loss of resident fish. The over-all result is that while the average individual remains a shorter time in an area than do individuals of the other species, the number of *P. wardi* in the patches remains stable over time.

That the three species have virtually identical requirements for space is evident in two ways. I have detected no tendency for a particular site within a rubble patch to be consistently occupied by individuals of the same species. When a resident disappears, its territory is frequently carved up among its neighbors, but members of the same species as the former resident are no more successful than others at gaining the vacated territory. Some unoccupied space, of course, is taken over by newcomers. This is how juveniles obtain territories in the first place. Yet newcomers do not settle more often than by chance into sites previously occupied by members of their own species. Nor is there any tendency for colonizing juveniles of any species to preferentially settle adjacent to adults of their own species. If the three species do have subtly different space requirements, and if the space within a rubble patch is best for one species here and better for another species elsewhere, I would expect that over several years, a succession of residents of one species would occupy a certain area of a rubble patch and juveniles would tend to settle near adults of their own species.

The indications are thus strong that these three species have very similar—if not identical—space requirements, are reasonably similar in their abilities to obtain these requirements, and are in competition for them. These are the conditions under which the principle of competitive exclusion would predict that only one species should ultimately prevail. Why then do three species occur here?

The answer appears to lie in three special features of this situation. Gause's axiom requires that competing species occupy a closed and stable environment. The environment occupied by these three species is neither closed nor stable. Furthermore, the competition involved is not one in which any particular species has a consistently greater efficiency than any other. Perhaps it is not surprising that the principle of competitive exclusion appears not to apply here.

The environment is open in the sense that all new recruits to a rubble

Heron Island

Valerie Taylor, Ron Taylor Film Productions

patch come from outside. Juvenile recruits, in particular, may have traveled hundreds of miles in the plankton from the rubble patch of their parents to the one they finally settle in. The residents of a particular patch produce pelagic larvae that can play no part in the subsequent settling of that area. And even if one species were to take over all the space in a particular patch, it would still remain open to recolonization by the other species the moment vacant space appeared within it.

The environment is unstable because of the manner in which living space within rubble patches is generated. On a coral reef there is both constant growth and frequent minor destruction of coral. These processes create new rubble patches while eliminating old ones. At the same time, the mortality and emigration of residents within rubble patches constantly alter the supply of vacant living space. There is no constant rate of production of new living space, and old living space may suddenly disappear. The species cannot adjust their reproductive effort to coincide with availability of new space.

In virtually all competition for territorial space, it is the resident fish, regardless of size or species, that will be superior to an invader. Being at home appears to convey a considerable psychological advantage in such struggles. Thus it is the chance event, rather than the relative competitive efficiency of the three species, that determines which species will occupy which newly vacant sites on a rubble patch. The proportions of individuals of the three species present on a rubble patch is the result of a series of chance colonizations, over time, as sites on that patch become available.

The importance of chance may explain why all the species of this guild produce pelagic larvae over an extended breeding season. This is a method of broadcasting potential colonists widely in space and time. And this, in turn, is a way of buying tickets in the lottery for living spaces.

I believe we can extend these ideas to many other guilds of reef fish. The majority of reef fish, although not necessarily territorial, are sedentary and appear more likely to be limited by a shortage of suitable living space than by a shortage of food or other resources. The vast majority of reef fish also produce pelagic larvae over a prolonged breeding season. Many groups of species are thus likely to be engaged in their own giant and continuing lotteries for living sites. With no species likely to win all the time or any likely to lose all the time, a diversity of species higher than predicted by Gause's principle can continue to coexist on the coral reef. □

Pomacentrus wardi *(far left)*, Eupomacentrus apicalis *(above)*, *and* Plectroglyphidodon lacrymatus *(left) all inhabit the reef crest and all compete against each other. Three factors contribute to their success at coexistence—the changeable habitat, the influx of juveniles, and the element of chance colonization.*

Gerald R Allen

ald R. Allen

Wandering Art

Text and photographs by Stanley Ira Hallet

They're trading their camels for trucks, but traditional Afghan drivers still consider decoration an important part of the caravan

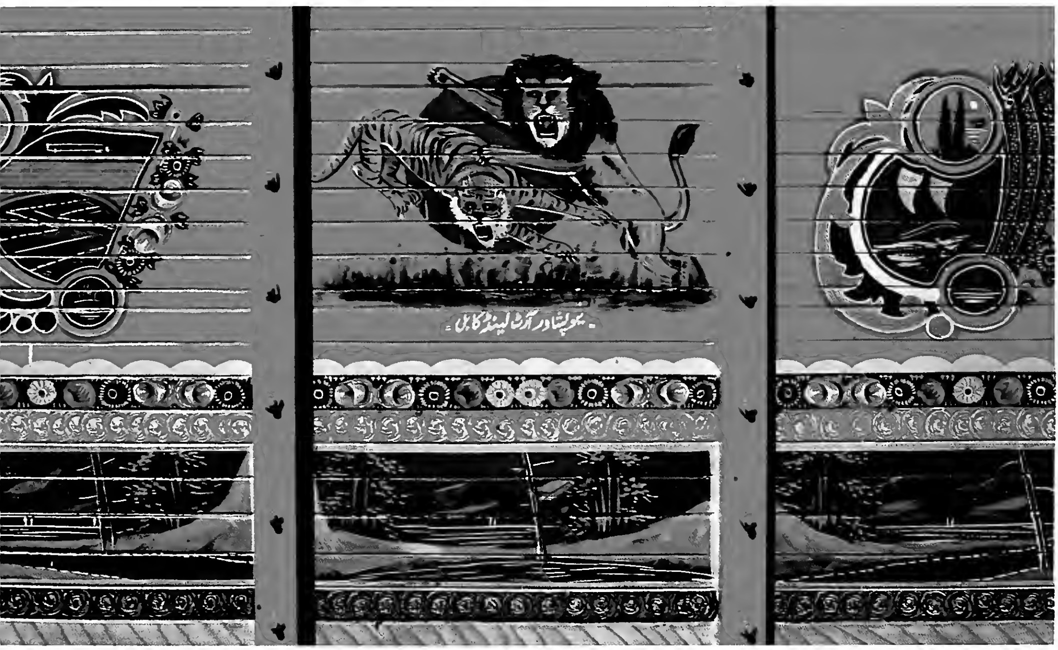
Until recently the only way to get around Afghanistan was by camel caravan. The landlocked country is barren, rugged, and mountainous. It has no navigable rivers and no boats—not even a train system. The only way to get goods from the urban centers to the hinterland was by contract with the nomads.

But even in Afghanistan times are changing. Afghanistan lies between Iran, Pakistan, the Soviet Union, and a tip of China, which means that everyone wants a piece of the country, and today's way of making friends is foreign aid. The latest game has been road building. The Russians build in the north, close to their own border, the Americans build in the south, and the roads meet somewhere in the middle on neutral ground. With the roads tying the country together, enterprising nomads, or *kochis,* are exchanging their highly decorated camel trains for trucks. These vehicles are not just a means of transportation, they are also becoming a part of the Afghan folk scene.

The trucks, built either in England or America, are stripped down to a motor mounted on a chassis to save transportation costs, shipped to Pakistan by boat, and finally carried overland to Kabul. In the Kabul truck yards, a big wooden box is built on the chassis and a grand cab is built around the steering wheel. The cab seats six across, with the driver to the left and passengers on both sides.

The trucks come in two basic types. The most popular is a four-cylinder English model, commonly called a "rocket" by the Farsi-speaking Afghans. This vehicle is used mainly on tar roads. Take it off the

Embellished Afghan trucks—with built-up cabs that seat six across, banners, chains, and brightly painted panels (detailed below)—bear a faint relation to the original English model.




BEDFORD
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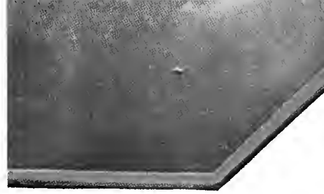
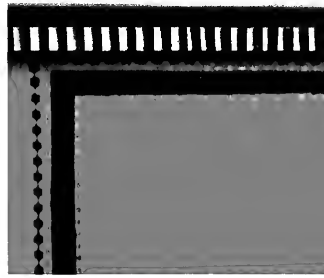
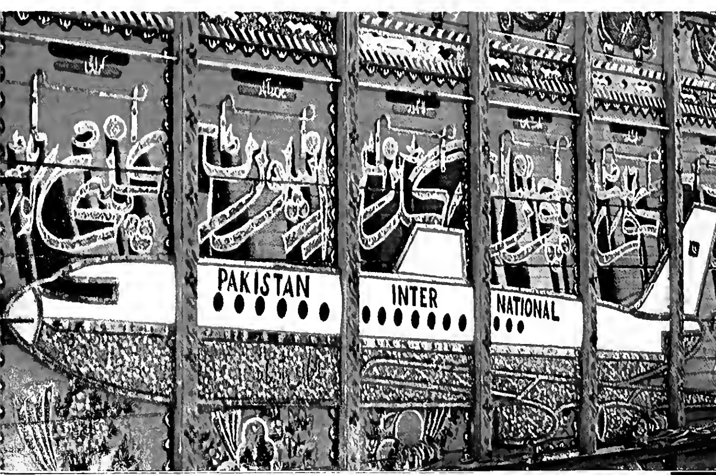
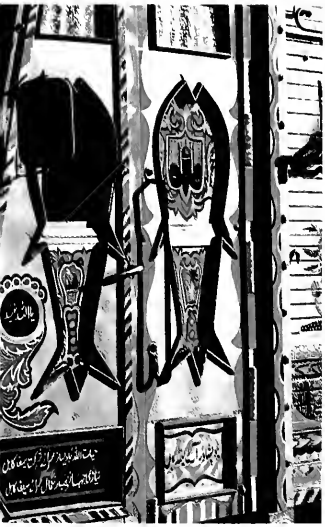
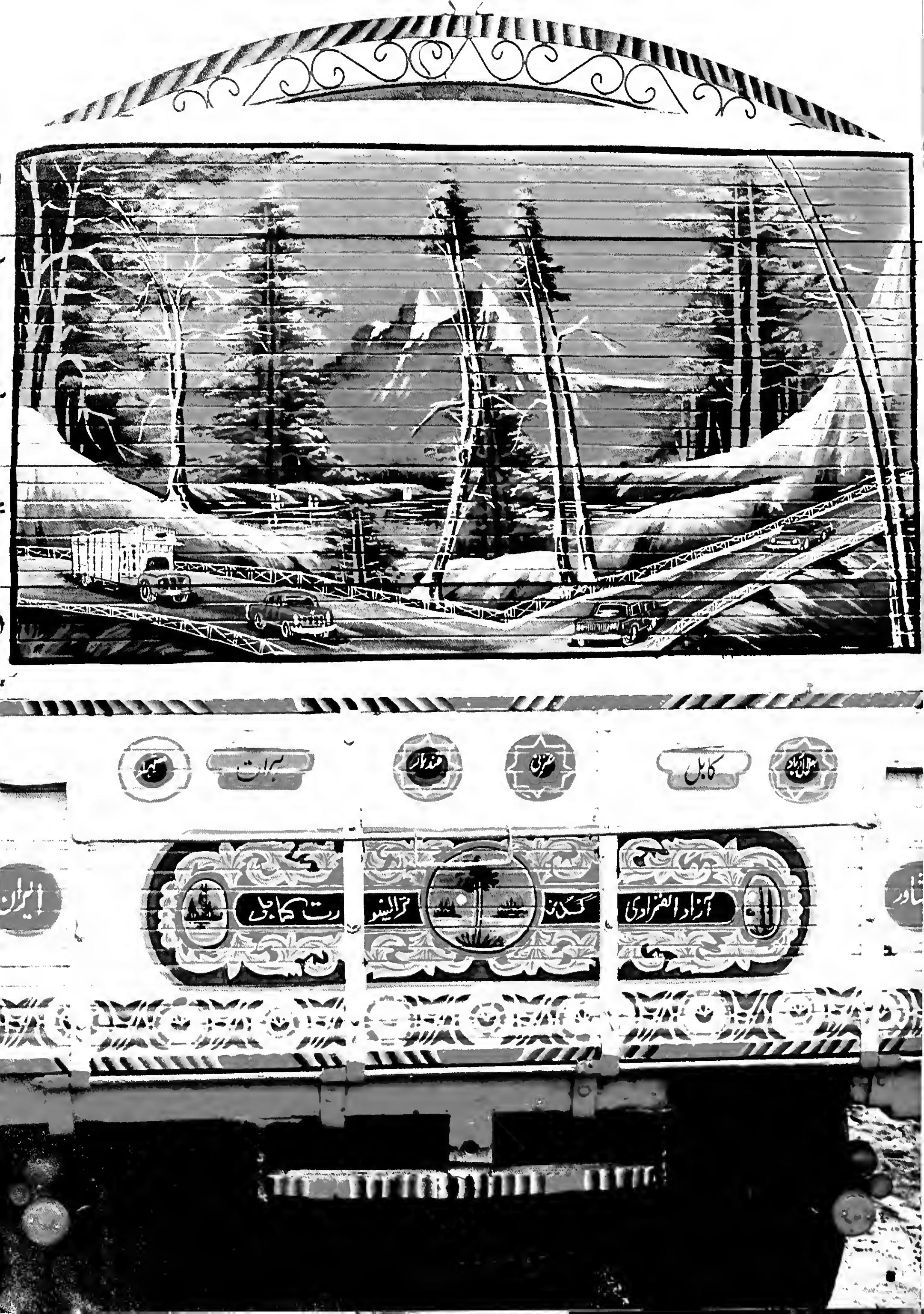




Details from a number of trucks show the variety of themes. Seductive women, copied from movie posters, are seen more often on trucks than on the streets of this strict Muslim country. A jet plane (done in bas-relief here), geometric patterns, and natural subjects, such as fish (which represent good luck), birds, and flowers, are all popular. Tassels, like those on camel blankets, fringe the cab; by reflecting the evil eye, glittery objects, such as mirrors and metal geegaws, provide protection. Applying the finishing touches to a palm tree, below right, a master painter will then sign each panel of the truck.







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آزاد انفرادی

The backs of trucks often depict modern highways running through idyllic mountain landscapes. Numbers on each of the panels insure that they will not be installed out of sequence.

asphalt strips and it will quickly fall apart on Afghanistan's infamous secondary road system. With a growing need to get into the inaccessible center of the country, the Afghans are now importing a new model, a six-cylinder truck with the nickname *shash* ("six," in Farsi). This vehicle, built in the United States, can easily take mountain passes that climb to 12,000 feet and is able to withstand a typical Afghan beating.

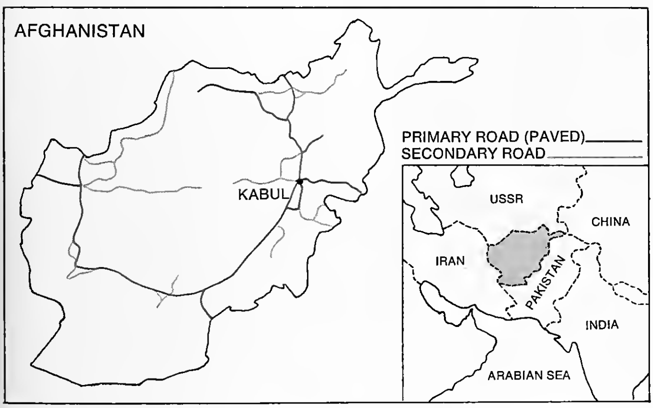
One of the first major alterations is made on the emergency brake. It is removed. In Afghanistan trucks are always beefed-up and reinforced to carry loads that no one in Detroit ever anticipated. Obviously, an emergency brake would not work under these conditions; therefore, rather than depend upon it, they take it out. In its place is an apprentice driver who hangs out the back of the truck and throws a wooden wedge behind the rear wheel to prevent the truck from rolling backward.

The highly colorful Afghan people have a long tradition of decorating all their personal goods; a plain wooden box of a truck is impersonal and alien. Thus, the decoration. As a beginning, chains hang from the front bumper, tassels, like those on camel blankets, fringe the cab; mirrors chase away the evil eye; and banners call upon Allah for protection. The wooden frame is painted in vivid swatches of color. Purples are easily played against oranges, and the outlined structural parts of the truck become part of an elaborate color scheme.

The owner of the truck makes only one "artistic" decision—which master painter will do the job. While the owner may suggest a few colors, the final design is the choice of the painter. The best painters are reputed to be in Peshawar, Pakistan, but Kabul also has many masters. Mohemmad Jahanzeb Niazi is one of the best in Kabul. His brothers have shops in Jalalabad, Afghanistan, and in Peshawar, where he himself spent an apprenticeship in much the same way that Western artists flock to the big cities. He now has eight or nine assistants.

Once the body of the truck has been built on top of the motor and chassis, metal panels are added to the sides. The metal sheets protect the wood from the elements, make it easier to wash the truck, and provide a perfect surface for the bright paints imported from Pakistan and Germany.

After the master lays out the basic designs and selects the ever important color scheme, apprentices, using a variety of templates, quickly paint the elaborate borders that frame each metal panel. Working freehand, without benefit of sketches or drawings, the master painter first prepares a rough cartoon of the main theme, then carefully paints in all the details with a fine brush.



When he is finished, the painter will sign his work several times, on each door as well as on the back of the truck. It takes ten days to paint a truck and can cost $100, equivalent to a driver's salary for four months.

Master painters use a variety of themes. Understandably, highly sophisticated religious symbols predominate. The flying Barak, half-horse, half-woman; the horse of Ali, son-in-law of Mohammed, who rode up to heaven; and Mecca and other holy Islamic shrines are all included. Because traveling in Afghanistan is hazardous, two eyes in front of the cab protect the truck from the evil eye.

In a dry, mountainous country, water becomes the second major theme. To remind Afghans of their Muslim paradise just around the corner, the sides of the truck are decorated with pastures, rivers, and mountains full of green trees and grazing animals. The back of the truck often consists of five horizontal panels depicting a glorious mountain scene. These are carefully numbered to insure that they will not be installed out of sequence when they are lowered into place after the truck has been loaded. What could be more refreshing when driving along a dusty dirt road than pulling up to the back of a truck that offers a tantalizing view of what might be just ahead?

Down the middle of this painted green valley lies a third theme: a winding Russian-American highway with cloverleafs, overpasses, and long-tailed Muscovite Cadillacs out for a Sunday drive. Other typical panels contain a black telephone with a lacquer-tipped feminine finger reaching for the dial—an anomaly in a strict Muslim country where women are still covered in full-length veils.

Many of the images are derived from colorful photographic calendars and imported Christmas cards. But in search of new subjects, painters now borrow from the display posters in front of the few movie houses in Afghanistan and depict scantily clad Pakistani leading ladies, in chains and being beaten. One truck-painting master we met expressed a desire for some plain-wrapped issues of *Playboy*, illegal in Afghanistan. We left him a centerfold. □

The Egg as Classroom

Even before they have hatched, many birds learn behavior that contributes to their survival later

Scientists are continually aware of the exquisite adaptive mechanisms by which animals survive. Through experimentation, we can unmask those creative mechanisms, exposing when they begin and how they function. For instance, immediately after hatching, a duckling, gosling, or baby chicken makes a durable filial attachment with its mother. It imprints on her, that is, fixes its attention on her, and thereafter follows her to whatever fate lies in store. This mother–offspring bond sustains the duckling through its precarious early weeks while it grows, learns about its environment, and becomes adept at avoiding the dangers of predators.

The tantalizing question is, how does the mother–offspring bond become so rapidly established? In earlier days many animal behaviorists might have said, "The bond is innate," and dismissed the inquiry. But that interpretation no longer satisfies; it offers no insight into the roots of behavior. It is patently obvious that, although hatching plunges the newborn bird into an entirely new milieu, it is the same individual as the prenatal one; hatching merely opens the shell. Thus it would seem that the bird must have been primed to make the filial attachment to an appropriate mother while still inside the shell.

Under natural conditions, mallard ducklings tend to leave the nest within a few days after hatching. During the posthatching, preemigrating stage, the noise level in the nest grows to a fever pitch as calls are exchanged between hen and offspring. These calls are a fundamental fiber of the social bond that is being strengthened between parent and offspring. Although a duckling has ample opportunity to learn its mother's range of calls before leaving the nest, research has demonstrated the ability of a freshly hatched duckling to pick not only its true mother but any appropriate mother, namely any hen of its own species, from among assorted mothers that belong to other, related species. The duckling is born with this ability because it has been primed, before hatching, to react selectively to a species-specific mother. A duckling can hear through the shell while still inside it. The embryo can hear its siblings in other shells, and it can hear its mother. Even more importantly, perhaps, it can hear itself. And its own sounds may be the most crucial primers.

Gilbert Gottlieb, a biopsychologist at Dorothea Dix Hospital in Raleigh, North Carolina, experimented widely with hole- and ground-nesting ducks and with domestic chicks. He raised some embryos alone, unable to hear other birds; some embryos together but without the hen; and some together and with the hen. Soon after these baby birds hatched, he counted how often they approached and followed silent, stuffed motherly models of their own and related types; stuffed models emitting "come-hither" calls through loudspeakers; or "mothers" that were nothing more than cooing loudspeakers. Rearing conditions did not seem to matter. Over-all, the loudspeakers, whether simulated birds or not, preempted the silent models. And, given a choice between its own species call and those of an-

During incubation, the calls of a mother duck can be heard through the shell by her embryo ducklings.

by Evelyn Shaw

James Simon, Bruce Coleman, Inc

other species, mallard ducklings, for example, the chicks clearly chose the calls of their own type. In a different experiment testing the priority system of the baby birds, an artificial stuffed mother of appropriate species gave the wrong call and a stuffed mother of inappropriate species gave the right call. The birds showed no concern for the mother's looks, but responded only to the sound of her voice. The right call was what drew the babies.

Since ducklings revealed their penchant for motherly sounds, Gottlieb and his associates decided to delve deeper into the antecedents of the response, necessitating a move backward in developmental testing time to the embryo stage. Ducklings, although they hatch on the twenty-seventh day after the start of incubation, begin to make sounds on the twenty-fourth day, when the bill, previously enclosed in a membrane, penetrates the air space of the egg. Embryos also clap their large bills with seeming spontaneity. But the bill clapping turned out to be something less than spontaneous; in fact, it indicated the embryo's sensitivity to changes taking place outside the shell. The rate of bill clapping increased, decreased, or remained constant as species calls were played to the embryo through a loudspeaker.

As early as the twenty-second day, several days before it uttered sounds of its own, the duckling was aware of the sounds of any mother of its own species type. In addition, embryos previously prevented from hearing their siblings did not react (by increasing bill clapping) to the mother's calls on the twenty-fourth day. Perhaps sibling calls serve to sensitize the embryos, to ready them for the next stage in development, namely, responding to maternal calls. Indeed, if embryos have their vocal cords cut and cannot make their own sounds, they cannot distinguish the calls of one species type from those of another. Nevertheless, they can discriminate within two days after hatching, indicating that the normal developmental timetable may have lagged momentarily but was not irreversibly slowed. Thus, it seems that the duckling can serve as its own stimulator, its own primer. By listening to itself, it becomes tuned to its mother at the optimal time in development.

In another species of bird, the guillemot, the artistry of auditory recognition is even more finely developed. Unlike the ducklings, which recognize the sounds of their own species type but select any mother of the right species type, the guillemot is far more precise; it "recognizes" only the calls of its true parents.

Vulnerable newly hatched ducklings are helped to survive because they respond only to the calls of hens of the appropriate species.

A colonial sea bird, the guillemot breeds on precipitous ledges overhanging the ocean and produces only one egg. This hazardous breeding site keeps even the most stalwart predators away, but it creates other dangers for the guillemot chicks. One misstep and a newly hatched chick may plummet into the sea. Chicks, therefore, tend to stay put and huddle in the rock crevices and in parental feathers. The only active birds are the adults, which fly out to sea to forage and return with food morsels for their insatiable chicks. When an adult alights on the rocks, it utters a feeding call. On hearing such a call, *all* the hungry chicks might scurry from their safe havens in the rocks to be fed. A horde of chicks rushing about, however, could result in catastrophe with many of them tumbling into the sea. This does not happen since the feeding call brings forth only one chick — the family heir or heiress. The parent recognizes its own chick, and more importantly, the chick knows its own parents, having evidently learned the characteristics of parental calls during the hatching process.

Leonard Lee Rue III, Bruce Coleman, Inc.

Hatching takes a number of hours, during which the guillemot embryo twists, turns, and utters calls. Both parents share the incubation, and the increased embryonic activity stimulates them to rise, gently turn the egg, and utter feeding or luring calls. The parental movement, in turn, stimulates the embryos to twist around and call again. This restimulates the parents, and so forth. Mutual stimulation may last for long periods during which the parent–offspring social bond is established and each chick learns the call of its parents. Thus, after hatching, when a parent returns to the nesting site and sounds a feeding call, only its own offspring, and no other, is tuned to that call, a beneficial adaptation for birds living in a most precarious habitat.

The embryos of still other bird species communicate with each other at hatching time. For example, in bobwhite quail, which nest in ground holes and have an average of ten to twelve chicks per nest, hatching takes place synchronously. Synchronous hatching appears to result from clicking sounds that the embryos begin to utter twelve to fifteen hours before the actual event takes place. In a manner not yet understood, these sounds slow down the development of advanced embryos while speeding up the development of retarded ones. Hatched together, all the chicks can be quickly guided in a group away from the nest into the safe underbrush. This prevents individual chicks from straying and protects them from the predation that might take place if they had to wait for their siblings to hatch.

Thus it is clear that the shell does not totally insulate the embryo from the world around it nor is the embryo a passive, nonresponding organism. Bird embryos experience the outside world through temperature fluctuation; humidity changes; gas ex-

changes; being turned and rolled; hearing parental breathing, heartbeats, and other movements; and in some species, hearing their own calls as well as those of their siblings and mothers. Developmental events within the egg apparently set the stage in such a way that the newly hatched bird has the ability to make appropriate responses to the new stimuli in its new environment.

In former times animal behavior was divided by those studying it into two categories: innate and acquired. If a behavior appeared right after an animal hatched or was born, it was generally labeled innate. If the behavior became manifest after the animal had been around for a while, it was, in all probability, labeled acquired. Innate behaviors were deemed to be programmed by the genes; acquired behaviors were thought to be derived from learning or other experiences. But this dichotomy proved to be highly troublesome; consequently, it is spurned by the breed of scientists who are currently probing the origins of behavior. Too many subtle and complex things happen as an animal is developing to permit such a simplistic categorization. The dichotomy was too rigid, too short-sighted, and worse, it closed off important avenues of research. Behaviors were labeled but not understood. Obviously, the fertilized egg contains genes that determine the future course of development. But between the gene and the expression of behavior, innumerable events take place that we are just

When ready to leave the nest, ducklings follow their mothers or any mothers of their species because the hens sound right.

beginning to probe. We have no idea how many genes are involved, how they are modified, how they interact; nor do we know the influential extent of an animal's experiences before birth or hatching. Even a simple event, such as momentary oxygen deficiency, may have a lasting effect if it occurs at a critical time.

The dichotomy may have served animal behavior when the field was in its infancy, but it no longer has any validity. We should recognize that genes do not determine a particular behavior, only the tendency to develop that behavior, given the appropriate environment at the appropriate time. And we must keep an open mind in assessing the ways in which the environment may modify inherited tendencies.

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Thase Daniel, Bruce Coleman, Inc.

Climatic Change on Mars

The Martian atmosphere may have once resembled that of early earth

With the *Viking* spacecraft now well on its way to a rendezvous with Mars this summer, the latest theories of the evolution of the Martian atmosphere provide the strongest hint yet that there may be some form of life on the Red Planet for the *Viking* landers to find. The theories are based on an analysis of more than 7,000 photographs of Mars taken by *Mariner 9* as it orbited the planet in 1972. Those pictures show the planet today to be largely an inhospitable desert so, of course, there is no chance of finding the intelligent life-forms and artificial canals of science fiction. But there are indications that Mars was not always so inhospitable, and that early in its history it may have possessed an atmosphere similar to that of the earth several billion years ago when life first appeared here. If so, there is reason to suppose that the same kinds of primitive life that arose on earth appeared on our neighboring planet as well—and if they did, their descendants may still be there today.

This new understanding of the atmosphere of Mars has gone through almost as many evolutionary changes as the atmosphere itself. In a sense, the story can be traced back to the nineteenth century, when some astronomers claimed that their telescopes revealed permanent, seemingly artificial features—the notorious "canals." Although no two astronomers ever seemed to see quite the same sets of markings, speculation that free water might exist on Mars, running if not in canals, then at least in natural rivers, lasted up to about ten years ago. These conjectures were dashed only when photographs of the early *Mariner* flyby missions of Mars were sent back to earth during the mid-1960s, showing what seemed to be a dry, lifeless, and unchanging planet very similar to the moon. But even that concept—which was based on photographs of a very small area of Mars—turned out to be grossly misleading when *Mariner 9* went into orbit around Mars in 1971 and, over a period of many months, produced a complete photographic map of the planet.

With the full picture before them, planetary astronomers now perceive Mars as a planet whose geology is continually evolving. Among other features, Mars possesses the biggest volcano known in the solar system—Olympus Mons—which rises fifteen and a half miles above its surroundings and encompasses a volume as big as that of all the volcanoes of the earth's Hawaiian chain put together. In addition, there is a great rift valley system in the equatorial region of Mars, as extensive as the East African Rift Valley on earth, and most exciting of all, there are many channels cutting across the dry Martian surface that give every appearance of having been carved out by running water, even though they are empty today. These are not the canals of former speculation, and they are far too small to be picked out from the earth even with the aid of telescopes, but their presence on a planet where water in liquid form does not exist today has posed a puzzle. When the latest piece of the puzzle clicked into place a few months ago, the hopes of all concerned were raised that *Viking* might find life on Mars.

One of the young scientists closely involved with the new view of Mars is Owen Toon, research associate at NASA's Ames Research Center at Moffett Field, California. Representing a group of planetary scientists, Toon described the processes of climatic change on Mars at a recent international gathering of experts on the terrestrial weather held in Norwich, England, to ponder the problems of our changing climate here on earth. By studying the workings of the atmospheres of other planets, we are placed in a much stronger position when it comes to interpreting—and predicting—climatic changes on earth. Thus, quite aside from the possibility of finding life on Mars, the valuable insights into planetary atmospheres derived from space probes like *Mariner* and *Viking* would alone be ample repayment for the effort and cost involved.

With the *Mariner 9* evidence before us, it is clear that there were once rivers, lakes, and floods of water on Mars. Photographs of sandbars, sinuous channels, delta regions, and many other features make that conclusion inevitable (*see* "Are We Alone in the Cosmos?" *Natural History*, June-July 1974). But liquid water cannot exist on Mars today because its surface temperature and atmospheric pressure are both so low that a bucket of water dumped on the Martian surface would either boil away or freeze. For the same reasons, carbon dioxide cannot exist as a liquid on the earth, but only as a solid (dry ice) or a gas. For liquid water to have existed in the quantities needed to fill all the Martian rivers now known, the planet's temperature must have been high enough so that only part of the water was tied up in ice.

As it turns out, a small increase in

either pressure or temperature will do the trick because if one variable increases, the other follows suit and both then increase rapidly. A rise in temperature, for example, would release carbon dioxide from the frozen "dry ice" polar caps of Mars or from the Martian soil, and the resultant thickening of the atmosphere would help to keep the poles warm. A thicker atmosphere would transport heat more effectively from the equator and would act as a thermal blanket, trapping heat that is now lost as the planet's surface radiates infrared energy to space. Such a thermal blanket, known as the greenhouse effect, is a major cause of the high surface temperature of Venus and the livable temperatures on the earth.

A higher Martian pressure and temperature were put forward in 1973 by a group at Cornell University as the first explanation of the Martian rivers. This hypothesis made climatic change on Mars plausible, but a mechanism to trigger the initial small pressure or temperature increases was still lacking until another group at CalTech discovered a wobble in the tilt of the Martian polar axis. The wobble means that every 100,000 years or so the polar caps "nod" toward the sun, and it seemed for a time that the cumulative effect of that behavior might warm up the whole planet. This theory caused quite a flurry at the time by raising hopes that more clement conditions might return to Mars again in due course, and that our descendants might one day have a pleasant planet right next door to earth. One might note that the earth, too, has small wobbles in the tilt of its polar axis. They are a principal element in some theories of terrestrial ice ages, but the wobble of the Mar-

tian tilt is much larger than the earth's.

Recent studies of the *Mariner* pictures unfortunately seem to rule out the wobble as a cause of the Martian rivers. There is no evidence that Mars has recently gone through repeated phases of wetness or, indeed, that the rivers we see today were created recently. Quite the opposite. The current view is that the rivers are at least 500 million years old and may have been dry for several billion years. Whatever their origin, the period of humidity on Mars took place during an epoch early in the planet's development.

This at first sobering revelation comes from analysis of the craters on Mars. Like those of the moon and Mercury, the Martian craters were produced by the impact of meteorites on the planet, and two features of the cratering pattern point to the antiquity of the flow of liquid water. First, although many of the larger craters show signs of erosion, indicating that the planet was wet *after* they formed, the smaller craters are still sharp edged. As we understand the history of the solar system, the very large craters are much older than the small ones, being relicts of the time shortly after the planets formed, so erosion of only the large craters implies that there was water to do the eroding only a long time ago.

The second indication of the antiquity of the Martian rivers comes from a count of the craters that overlap dried-up rivers. A river bed is a small target, and we cannot yet be exactly sure how many new craters are formed by impacts each year or each million years. But there is enough evidence to show that the rivers are very old features and that meteorites have rained down over them for at least 500 million years.

The age of the rivers is the latest piece to be fitted into the puzzle of climatic change on Mars. If the planet is geologically active and has experienced intense volcanism, as the evidence seems to show, then the origins of the Martian atmosphere must have been similar to those of an atmosphere on the earth. Paradoxically, the present atmosphere of our own planet would be highly poisonous to the forms of life that first evolved here. We know that our planet must initially have had an atmosphere rich in such compounds as methane and ammonia, produced by outgassing from rocks and volcanic activity. Mars (and almost certainly Venus) must have started out in the same way. But those planets have since followed different paths as their atmospheres have evolved.

The present differences between the atmospheres of Mars and earth arise in part from Mars being farther from the sun and therefore a little cooler, but they derive chiefly from Mars being a smaller planet with a weaker gravitational pull. Mars's thick early atmosphere of methane and ammonia would have helped to keep the planet warm and its rivers flowing. Even at what we regard as comfortable room temperatures, however, many light gases, especially hydrogen, would have been warm enough for the kinetic energy of their molecules to carry them outside the pull of Martian gravity, thereby thinning the atmosphere in accordance with the following sequence of events.

Gases such as methane and ammonia are composed of hydrogen chemically bonded to elements such as carbon and nitrogen. Sunlight can break these chemical bonds, freeing the hydrogen to escape. The leftover carbon and nitrogen molecules on Mars, which would have been too heavy to escape the planet's gravity, would then have combined chemically with surface materials and become locked up in rocks. Oxygen would also have been produced when sunlight broke up the water molecules, and some of it would have combined with the carbon to form carbon dioxide. In this way, the early atmosphere of Mars could have evolved from a thick wet cover into the thin, cold, and dry blanket of carbon dioxide we see today.

The possibility that the Martian atmosphere could have evolved in this manner was recognized even before the *Mariner 9* mission to Mars. But no one then knew how dense the original atmosphere must have been or how long it might have survived. Toon reported at the Norwich meeting that the existence of ancient Martian rivers indicates that the early atmosphere of Mars must have been both dense and long lasting. This conclusion is of great interest to planetary scientists because an early atmosphere of methane and ammonia and warm pools of liquid water were the very conditions that led to the origin of life on earth.

If it once started, could life on Mars have adapted to the dramatic atmospheric change outlined above?

Remembering that we are talking about the equivalents of such hardy terrestrial plants as lichens, such a possibility seems quite likely. The atmosphere of the earth has undergone equally dramatic changes since the first gases surrounded our planet. Although oxygen is essential to the well-being of everyone reading this article, it is poisonous to the earliest forms of terrestrial life. By analogy, one can imagine some form of extraterrestrial intelligent life reasoning that life could not possibly survive in the earth's present corrosive atmosphere and that the early life-forms on earth must therefore have all died out by suffocation in their own wastes—namely, the very oxygen we earthlings need for survival.

The great advantage of oxygen if you *can* adapt to it is, of course, that its energetic chemical activity provides a good basis for the development of energetic active life-forms. There are not very many active trees or energetic lichens, both forms of life that obtain their energy by methods other than the use of oxygen. But with their lower energy requirements, plants can adapt to harsher environments than animals can, and on the basis of the present understanding of Mars we can guess that some hardy lichens from the Antarctic might survive if they were shipped to Mars.

We know that water is present in the Martian soil although no longer in the planet's rivers, and it is by no means impossible that there is life in the soil as well. Even if there is life, however, the first *Viking* landers may not find it, just as the early *Mariner* pictures failed to show us a representative view of Mars. But if life is discovered on Mars, it will indicate that this is a natural development from those conditions both Mars and the earth experienced in their youth. And since there must be many other planets in our galaxy, as well as in other galaxies in the universe, that have been through similar stages in their evolution, there would be a strong implication that life exists in many other parts of the universe. The possibility that earth may not be a special cosmic case is what makes the prospect of finding even a humble lichen on Mars of such great importance.

John Gribbin, a member of the Science Policy Research Unit at the University of Sussex in England, is now studying climatic change on earth.

by Raymond Sokolov

A Steak in the Future?

Perhaps not, if ethical and economic considerations prevail

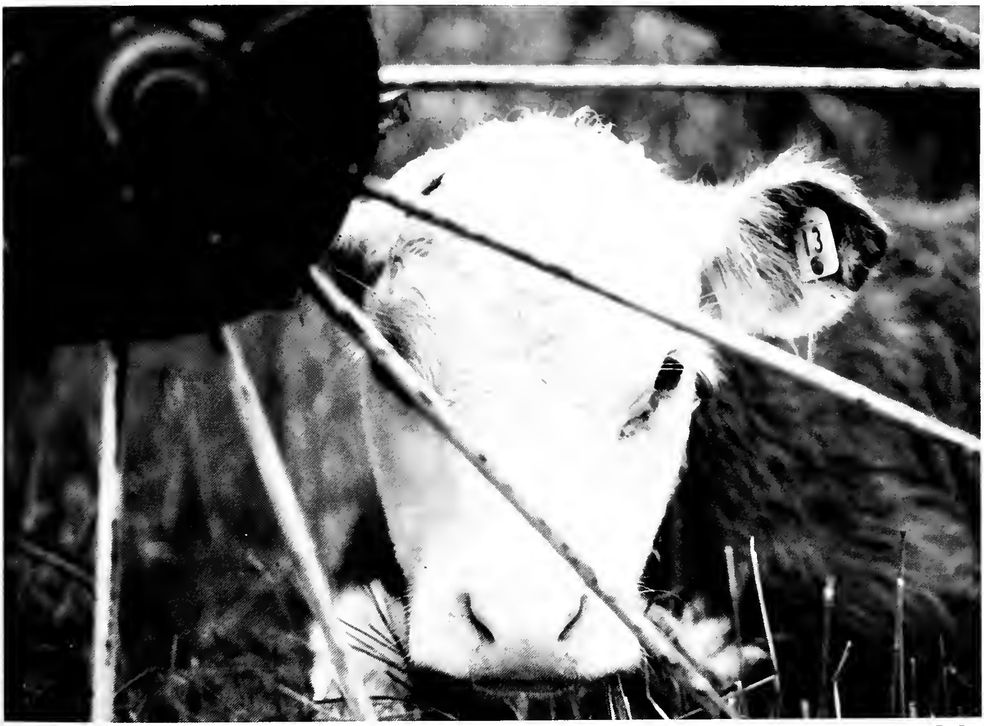
During the recent beef crisis, I attended a dinner party on Park Avenue at which the main course, to the astonishment of even the most recklessly profligate of the guests, was a standing rib roast. A tub of golden caviar could not have startled me more, and as I bit into the tender, delicious meat, I felt as if this might be my last plateful of the food I was raised to think was essential to a normal American life.

Since that day the price of beef has dropped a bit, and a spate of other crises has taken the urgency out of the beef question. Now that everything costs more than it did a few months ago, we are not so fretful as we were about the price of steak. And yet, the serious questions about our national diet that were raised so vividly during the beef crisis remain unresolved. Beef is still a national addiction. Per capita consumption of beef in the United States is running at well over 100 pounds a year, which is close to double the amount people were eating in 1941, the year I was born. In absolute terms, Americans consume more than 20 billion pounds of beef annually.

And that *is* hay, not to mention all kinds of other expensive fodder. Generally speaking, it takes eight pounds of feed grain to produce one pound of quality beef. This is a lavish way to feed ourselves. Indeed, it is hard to argue with the beef Jeremiahs who have been decrying the waste of food inherent in beef production.

An anthropologist who studied the American diet might justly conclude that our national beef fetish was a subtle form of potlatch—a conspicuous destruction of resources for a presumably ritualistic reason. Well, not quite. At those thousands of shrines known as hamburger stands, the faithful do actually eat the sacramental patty.

This, to me, makes more sense than the pure worship of cow flesh that is practiced in India. None of the approximately 180 million holy cows is eaten, slaughtered, or exported.



Tom Page

This great horde of bovines is, in fact, the largest national herd in the world. India supports one entire beast for every three Indians. Some of the Indian cattle are milked but in amounts too small to show up on statistical tables. Also, cattle dung is an important source of fuel, which unfortunately means that it does not get plowed into the depleted Indian soil, whose grass cover has been cropped bare by ravenous cows. When Indian cows grow old, they can spend their declining years in state-operated bovine rest homes.

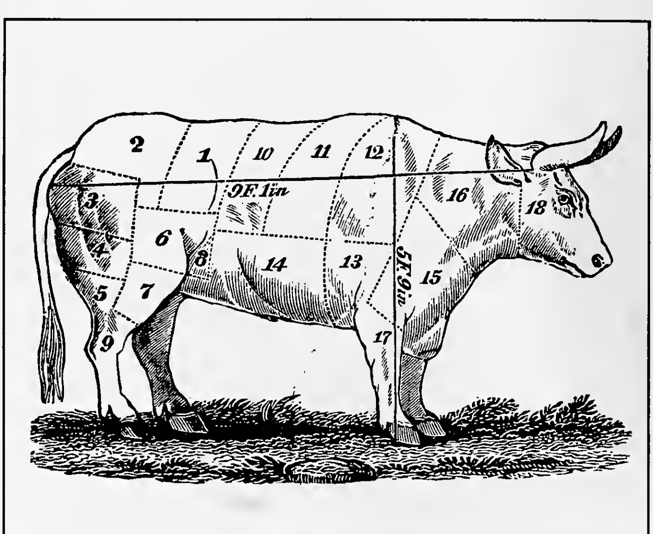
Since the lion's share of global malnutrition is Indian, it is tempting to wring one's hands in disgust at the pathetic paradox of the holy cow, and it is also tempting to write off Indians as kamikazes of the flesh who do not merit world aid for their self-inflicted wounds. But we in the West can, on close inspection, look as repellent and irrational in our sadism against bovines, as Indians do in their masochism.

Sadism? Yes, for here are just a few things we do to fellow mammals fully capable of feeling pain and fear. We chain them up in barns for months and years; we poleax them; we brand them; we spirit their young away for veal; we pack them into feedlots to fatten them for market and there let them end their days waddling about on hills of their own manure. By the end of this process, even an amateur can identify a prime-grade steer: it is so fat that it cannot walk normally.

Instances such as these have led Peter Singer, an Oxford philosopher from Melbourne, to call, in rigorous philosophical terms, for the end of "tyranny of human over non-human animals." In *Animal Liberation: A New Ethic for Our Treatment of Animals*, Singer argues that meat production is as indefensible as racism and sexism. He means that the same reasons that have led us to give equal consideration to members of different races and of the opposite sex must logically be applied to members of other species as well.

This is not the place to expound Singer's argument in full detail. His book is, however, a powerful tract, rationally set forth, against the horrible results of our too great solidarity as a species. Singer, although himself a vegetarian, is no fanatic. "It is probably true," he writes,

> that comparisons of suffering between members of different species cannot be made precisely, but precision is not essential. Even if we were to prevent the infliction of suffering on animals only when it is quite certain that the interests of humans will not be affected to anything like the extent that animals are affected, we would be forced to make radical changes in our treatment of animals that would involve our diet, the farming methods we use, the experimental procedures in many fields of science, our approach to wildlife and to hunting,



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trapping and the wearing of furs, and areas of entertainment like circuses, rodeos and zoos. As a result, a vast amount of suffering would be avoided.

Even without endorsing this position, we acknowledge the violence of the carnivorous life by our very speech. The English language disjoins the meat we eat from the animal that produced it. Steers (and sometimes cows) give us beef. Calves grow veal. Pigs turn into pork. Lamb—the exception that proves the rule—stays lamb, but sheep becomes mutton at the butchers and hunters kill deer but consume venison. Even goat is renamed chevon when we serve it.

This linguistic ruse, which gives the living animal his Anglo-Saxon name on the hoof but labels him with a more remote, meat-specific name derived from French when he is dead and sold as food, allows us to disregard the cruelty inflicted by our meat hunger. Perhaps this is a sign of civilization. If so, it is a civilization still red in tooth and claw but careful to wash up after the hurly-burly's done.

The modern human carnivore is also a far more effective predator against other species than was his naked, matted, club-wielding forebear. Today, we have industrialized livestock production and slaughter. And through artificial insemination we have brought a brave, new, and involuntary world of eugenics to the barn. After centuries of selective breeding, the milch cow is now little more than a machine for transforming hay into milk. The beef animal specializes in muscle development. The lacteally prodigious Holstein and the thewy Hereford are, in a sense, human inventions, virtually technological variations on the same basic system. The same engine runs them both. It has four stomachs and chews its cud.

Rumination, as the bovine energy process is known, is a creative method of vomiting. It allows cattle and other true ruminants (deer, oxen, sheep, goats, and giraffes) to graze in haste and chew at leisure. The animal swallows his food whole (unchewed) and takes it into the largest of four stomach chambers: the paunch, or rumen. Later, the food is regurgitated into the mouth, where it is chewed and mixed with saliva. Reswallowed, the cud descends to the second stomach, or reticulum, so called because

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the mucous membranes form a network, or honeycomb. This lining is the honeycomb tripe so highly prized in tripes à la mode de Caen (see recipe below) and other tripe recipes.

Digestion continues in the third stomach, variously called the omasum, the psalterium, or the manyplies. Its leaflike folds have reminded certain observers of the pages of a psalter or of a manifold (manyplies). Finally, the cud progresses to a rennet bath in the last stomach, the abomasum, whence it makes its final digestive sortie through the intestine.

Viewed from without, rumination looks pleasantly sedentary and contemplative. When we say a person is ruminative, we mean to praise him for his thoughtful mien. And in most poetic references, cud-chewing cattle are metaphors of placidity and contentedness. But this is euphemism. In our hearts, we disdain slow-witted, cud-chewing cows. When the Lord wished to humiliate Nebuchadnezzar, he saw that the once-mighty master of Babylon "was driven from men, and did eat grass like oxen, and his body was wet with the dew of heaven, till his hairs were grown like eagles' feathers, and his nails like birds' claws [Dan. 4:33]."

Am I trying to persuade you to take up the cudgels for bovine equality with Peter Singer? Has he, as it were, cowed me into vegetarianism? Not quite. For one thing, I can see no ethical objection to eating animals that have died natural or accidental deaths (for example, road-killed deer), even by Singer's standards. Generally, moreover, I object to vegetarianism on esthetic grounds. Meat, I think you will agree with me, has a nice taste. No doubt, I could learn to make do with alternate protein sources. Indeed, I do not eat meat every day. But I cannot deny that I enjoy it when I do bite into a rare steak. And I doubt that I will make a dent in the worldwide trend toward ever higher meat consumption if I embark on a program of acorn eating (officially, balanophagy) or some other nonmeat diet. Probably, excess population and food scarcity will cut this Gordian knot for us. By the turn of the century, beef cattle may have vanished like the dodo. In the meantime, I prefer to stifle my guilt, eat a corned beef sandwich now and then, and do my evangelical best to prevent my own species from exterminating itself through war.

Raymond Sokolov is a free-lance food writer and novelist.

Tripes à la Mode de Caen

2 pounds honeycomb tripe
3 carrots, peeled and cut in rounds
½ pound salt pork, sliced
1 sprig parsley
1 bay leaf
¼ teaspoon thyme
6 garlic cloves, peeled
3 cloves
1 cup chicken stock
1 cup dry white wine
Salt
Pepper

1. If you are using frozen, ready-to-cook tripe, simply defrost and rinse. Fresh tripe should be soaked for several hours.
2. Preheat oven to 250 degrees.
3. Cut the tripe into two-inch squares.
4. In a heavy casserole, place one-third of the tripe in an even layer on the bottom. Cover with layers of half the carrots and salt pork. Cover that with the parsley, bay leaf, thyme, 3 garlic cloves, 2 cloves.
5. Add another layer of tripe (one-third the original amount). Top it with layers of the remaining carrots and salt pork. Add remaining garlic and cloves. Add a final layer of tripe. Pour in chicken stock and white wine. Add more stock to bring liquid level up to the top of the tripe if necessary. Season lightly with salt and pepper.
6. Cover the pot with a double thickness of aluminum foil. Press the lid on to make a hermetic seal. Bring to a boil on stove; then place in oven and cook for 12 hours.
7. Remove casserole from oven. Adjust seasoning of broth. Spoon away excess fat and serve. Or for a more elegant effect, separate out the tripe squares and discard all other solid ingredients. Let the sauce cool in the refrigerator so that you can completely defatten it after the fat rises to the surface and solidifies. Then, put the tripe back into the sauce, heat to a simmer, and serve on hot plates.

Yield: Four servings.

Celestial Events

by Thomas D. Nicholson

Sun and Moon During the last half of February and in early March, the sun is moving northeastward through the constellation Aquarius. About March 12, when it is within three degrees of the equator, the sun moves into Pisces, where it will arrive at the vernal equinox later in the month. In this part of the sun's annual journey, the duration of daylight increases by more than five minutes each day.

In February and March, new moon occurs at the beginning and end of the month, and the moon reaches its full phase near mid-month. About midway in the first week of both months, you can expect to see the early crescent show up in the evening. Each night thereafter, it will wax, stay longer, and set later, until—when it is full—it remains in the sky from sundown to sunup. After that, it wanes, rises later in the night, and remains past sunrise to become part of the daytime sky, until it disappears as a late crescent a few days before the next new moon. First-quarter moon is on the 8th of both months, full moon on the 15th. Last-quarter is on February 22, new moon on the 29th.

Stars and Planets Three planets—Jupiter, Mars, and Saturn—appear in the evening sky of February and early March. (All of them are shown on the monthly Star Map.) Brightest of the three is Jupiter, easily picked out among the dim stars of Pisces.

Mars becomes visible high in the south, just above the stars of Orion. No longer the brilliant object it was in December and early January, it is still very similar in appearance to two bright and nearby reddish stars, Betelguese (in Orion) and Aldebaran (in Taurus). Forming a nearly perfect isosceles triangle with them, Mars is the highest of the three. Saturn is still in Gemini, close to, and in line with, the bright twin stars Pollux and Castor. Mars sets at about midnight, Saturn a few hours before dawn.

Venus, still a bright star in the morning sky, is rather low in the southeast and not nearly as bright or prominent as it was earlier in the winter. By mid-March it will be very difficult to see.

February 16: Mercury is at its greatest distance to the right of the sun (westerly elongation), a position that ordinarily places it favorably as a morning star. But this is not a good cycle for the planet; it does not rise high enough to be seen before sunrise.

February 17: The moon is at perigee, nearest earth.

February 18–19: On both nights, the moon rises late, several hours after dark, and near the bright star Spica, in Virgo. Spica is east (left) of the moon on the night of the 18th, to the west (right) on the 19th.

February 27: You should be able to see Venus near the late crescent moon shortly after dawn this morning.

March 3: The moon is at apogee, farthest from earth.

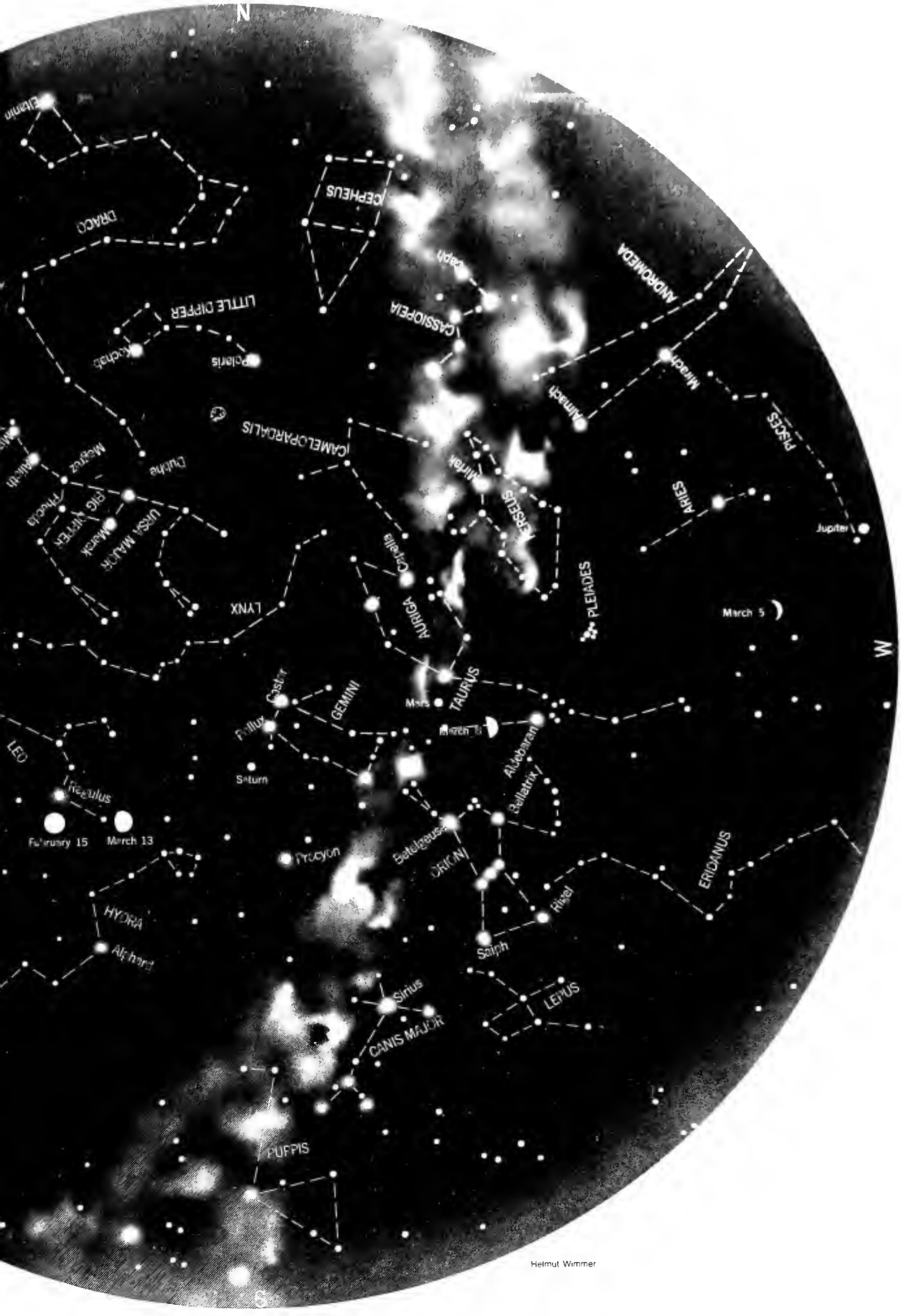
March 4: The bright object near the crescent moon this evening is Jupiter.

March 9: The moon, one day past first-quarter, is moving slowly to the left beneath Mars.

March 11: The moon appears below Saturn this evening. At about 11:00 P.M., EST, you will see the moon, Saturn, Pollux, and Castor, in that order, almost exactly in line, one above the other.

March 15: The moon is full at about 10:00 P.M., EST, and arrives at perigee about 2:00 P.M., EST, tomorrow. The effect of perigee, added to the spring tide, will result in extreme tides on the 16th.

★Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 10:15 P.M. on February 15; 9:20 P.M. on February 29; and 8:25 P.M. on March 15; but it can also be used for an hour before and after those times.



Helmut Wimmer

Books in Review

An Illustrator's Portfolio

by Murray Tinkelman

THE FANTASTIC CREATURES OF EDWARD JULIUS DETMOLD. Text by Keith Nicholson. *A Peacock Press/Bantam Book, $6.95; 96pp., illus.*

This is mainly a picture book—a collection of the work of Edward Julius Detmold who, with the collaboration of his twin brother, Charles Maurice, produced drawings that are outstanding for their imaginative treatment of the natural world. The brothers, born in London in 1883, were educated by an uncle whose interest in natural history served as encouragement for them to study and draw the animals they saw in the surrounding zoos and natural history museums.

The book is divided into roughly four sections, the first showing examples of the 1903 illustrations for Kipling's *Jungle Book* by both Edward and his brother. Interestingly enough the best piece in this section, the python in plate 5, is by Charles Maurice. *The Fables of Aesop* (1909), done after the death of Charles Maurice, is a series of delicate allegorical illustrations, strongly influenced by the Japanese prints that were becoming popular at that time.

But it is in the series of paintings for *Fabre's Book of Insects* (1921), where his intent is perhaps more humble, that Edward Detmold produced his finest work. By using almost cinematic techniques—extreme close-

Murray Tinkelman, an illustrator, is associate chairman of the Department of Illustration at Parsons School of Design, New York.


Princess Mary's Gift Book (1914)

Kipling's *Jungle Book* (1903)

ups, worm's-eye views, and unusual composition—he achieves a lyrical surrealistic effect. Although the Dürer influence is undeniable, these are the most intensely personal paintings in the book—elegantly composed, lovingly rendered, and keenly observed. Like the paintings of John James Audubon, they are the work of an artist, naturalist, and reporter. The book ends with six fine plates from *The Arabian Nights.* Lavishly decorative, they demonstrate the artist's ability to portray the bizarre and the fantastic, and not suffer by comparison with such great illustrators as Edmund Dulac, Rene Bull, Harry Clarke, and others of that genre.

The text, however, spends far too much time discussing Detmold's brother—from childhood collaborator to tragic young suicide. It also refers to pictures that don't appear in the book. If, in fact, some of Detmold's best illustrations were done for the *Life of the Bee* and *Hours of Gladness,* why are they not shown?

Fabre's *Book of Insects* (1921)

The Arabian Nights (1922)

Additional Reading

Bandicoot Rats (p. 10)

S.A. Barnett's *The Rat: A Study in Behaviour* (Chicago: Aldine Publishing, 1963, $3.95) has a full bibliography with more than 350 references to other studies in the field. Although it was published thirteen years ago, this book remains the most complete and useful treatment of the behavior of wild and tame rats. Two pertinent 1968 publications of the U.S. Public Health Service—R.Z. Brown's "Biological Factors in Domestic Rodent Control" and H.G. Scott and M.R. Borom's "Rodent-borne Disease Control Through Rodent Stoppage"—may be obtained from: Public Inquiries, Center for Disease Control, Atlanta, Ga. 30333. The first is a 32-page booklet dealing with basic rodent biology—behavior, population dynamics, and reproduction of *Rattus rattus*, *R. norvegicus*, and *Mus musculus*. The second deals more specifically with problems of ratproofing areas of food and refuse storage and, as such, describes the modes and means of the domestic rat's adaptations for living off man's carelessness. See also J.B. Calhoun's classic monograph, "The Ecology and Sociology of the Norway Rat," published by the U.S. Public Health Service in 1962 and available in most libraries. In a recent issue of *Science* devoted entirely to the world food crisis, J.D. Gavan and J.A. Dixon's "India: A Perspective on the Food Situation" (vol. 188, pp. 541–549) and "Crop Protection to Increase Food Supplies," by W.W. Ennis, Jr., et al. (pp. 593–598) are particularly relevant to Frantz's account of bandicoot rats and rice storage.

Rifting in Botswana (p. 34)

C.F. Richter's *Elementary Seismology* (San Francisco: W.F. Freeman, 1958), a primary source of earthquake information (including discussions of the seismicity of Africa), and the 3rd edition of A.L.

Dutoit's *Geology of South Africa* (New York: Hafner Publishing, 1953) are classic texts available in most university libraries. For a nontechnical account of plate tectonics and continental drift see A. Hallam's *A Revolution in the Earth Sciences* (Oxford: Clarendon Press, 1973). *Debate About the Earth: Approach to Geophysics Through Analysis of Continental Drift*, by H. Takeuchi et al. (San Francisco: Freeman, Cooper & Co., 1967), presents an analysis of the debate that has ensued since A. Wegener published his theory of continental drift in 1912. As a further historical note, see Dutoit's review of ideas on continental drift up to 1936 and the statement of his own theoretical position in *Our Wandering Continents: An Hypothesis of Continental Drifting*, which has recently been reprinted (Westport: Greenwood Press, 1972). Clear expositions of the process of shifts in the earth's crust and resultant rift systems are found in two recent *Scientific American* articles: J.F. Dewey's "Plate Tectonics" (1972, vol. 226, no. 5, pp. 56–68) and H. Tazieff's "The Afar Triangle" (1970, vol. 222, no. 2, pp. 32–40).

Alpine Avalanches (p. 44)

Anthropologist John Friedl's recently issued paperback, *Kippel: A Village in the Alps* (New York: Holt, Rinehart & Winston, 1974, $3.25), develops more fully many of the points made in his present *Natural History* article. *The Hidden Frontier: Ecology and Ethnicity in an Alpine Valley*, by J.W. Cole and E.R. Wolf (New York: Academic Press, 1974), provides useful background information on the interplay of environment and psychology on contemporary cultural changes taking place in central Europe. "Of Men and Meadows: Strategies of Alpine Land Use," by R.M. Netting (*Anthropological Quarterly*, 1972, vol. 45, pp. 132–144), deals specifically with man's adaptations to the unique characteristics of village and farm life in avalanche-prone areas.

Bats (p. 52)

A. Novick and N. Leen have published an expensive but colorful volume, *The World of Bats* (New York: Holt, Rinehart & Winston, 1970). This large-format, "coffee table" book contains dozens of Leen's excellent color photographs, which capture both the individuality and characteristic behavior patterns of each species depicted. Harvard mammalogist Glover Merrill Allen, whose thinking as reflected in his writings was far ahead of his time, published his classic book *Bats* in 1939; it has been reprinted in an inexpensive paperback edition (New York: Dover Publications, 1967, $3.50). This volume contains chapters on "bat-flowers," bat biology, behavior, and sonar, as well as on bats in folklore, bats as pets, and even bats as food. *The Biology of Bats*, a two-volume reference work edited by W.A. Wimsatt (New York: Academic Press, 1970), is a compendium of recent research intended for the working zoologist. K. Faegri and L. van der Pijl's *The Principles of Pollination Ecology* (2nd ed. Elmsford: Pergamon, 1972) is a modern, balanced source book that deals with the role of bats in pollination, while B.J. Meeuse's *The Story of Pollination* (New York: Ronald Press, 1961) is a well-illustrated, semipopular book dealing with general principles of pollination and with the various classes of pollinating agents. Botanist van der Pijl, who coined the term *chiropterophily*, described bat pollination in his review paper, "Evolutionary Action of Tropical Animals on the Reproduction of Plants" (*Biological Journal of the Linnean Society*, 1969, vol. 1, pp. 85–96). H. Baker, another expert on pollination, discussed the influence of animals on plant evolution in "The Adaptation of Flowering Plants to Nocturnal and Crepuscular Pollinators" (*Quarterly Review of Biology*, 1961, vol. 36, pp. 64–73). L.E. Gilbert and P.H. Raven have recently edited *Coevolution of Animals and Plants* (Austin: University of Texas Press, 1975), in which a diversity of botanical and zoological information—concentrating on interactions between flowering plants and their pollination or seed dispersal by insects, rodents, and birds—is woven together in support of coevolution as an important process in community evolution.

The 1975 index for NATURAL HISTORY may be obtained by writing to: INDEX Natural History, Central Park West at 79th Street, New York, N.Y. 10024

Reef Fish (p. 60)

Unfortunately, many of the best books on the Great Barrier Reef have been published in Australia and are of limited availability in the United States. Isobel Bennett's *The Great Barrier Reef* (Melbourne: Lansdowne Press, 1971) and *The Great Barrier Reef and Adjacent Isles*, by K. Gillett and F. McNeill (Canberra: Coral Press, 1967), are two recent examples. Classic works from the 1930s, such as T.C. Roughly's *Wonders of the Great Barrier Reef* (the 13th edition was recently reprinted, Mystic: Lawrence Verry, 1966, $11.00) and particularly, C.M. Yonge's *A Year on the Great Barrier Reef* (New York: Putnam, 1930) are good sources of specific information presented with the excitement of pioneering explorations. Craig McGregor's *The Great Barrier Reef* (Amsterdam: Time-Life International, 1974, $7.95) is a well-written and superbly illustrated account of the interacting physical and biological worlds in the reef habitat. E.O. Wilson's *Sociobiology: The New Synthesis* (Cambridge: Harvard University Press, 1975) provides a perspective on reef fish behavior in relation to the rest of the animal kingdom. A collection of papers edited by B.B. Collette and S.A. Earle, "Results of the Tektite Program: Ecology of Coral Reef Fishes" (*Natural History Museum of Los Angeles County, Science Bulletin 14*, October 30, 1972), offers several interpretations of coral reef fish distribution in Caribbean waters, including "Space Resource Sharing in a Coral Reef Fish Community," by C. Lavett Smith and J.C. Tyler (pp. 125–170). This article is an example of how two scientists, studying similar behavioral and ecological aspects of reef fish as those Peter Sale reports on from Australia, can arrive at different conclusions. Three other articles from this collection report on feeding behavior, escape responses, and activity patterns in coral reef fish.

Afghan Trucks (p. 66)

Nancy Hatch Dupree's *An Historical Guide to Afghanistan* (Kabul: Afghan Tourist Organization, 1971) presents detailed descriptions, in a convenient and informative format supplemented by twelve maps and over sixty photographs, of each major site of interest along the highways of modern Afghanistan. Perhaps the definitive study of the country, however, is to be found in Louis Dupree's *Afghanistan* (Princeton: Princeton University Press, 1973), an encyclopedic account of the land and the people, the past and the present, of this central Asian country. Two 16-mm documentary films, *The Painted Truck*, by Judith and Stanley Hallet and S.C. Schroeder, and Judith and Stanley Hallet's *The Nomads of Badakhshan*, provide a more graphic understanding of several important aspects of Afghan life. *The Painted Truck*, for instance, deals with a particular Afghan phenomenon, the personalization of private goods through elaborate hand decoration, in this case the heavy-duty trucks that are fast replacing camels as the major mode of moving goods and people about the country. The second film explores the meaning of nomadism and reveals the cultural basis from which the subjects of the truck film—the men as well as their vehicles—have evolved. These films, each in color and just under thirty minutes in length, may be available locally or contact Film Images, 18 West 60th Street, New York, N.Y. 10023 for rental or purchase information. For another perspective on artistic expression as a clue to the cultural sense of a people see R. Sommer's "People's Art" (*Natural History*, 1971, vol. 80, no. 2, pp. 40–45) and Eric Kroll's "Folk Art in the Barrios" (*Natural History*, 1973, vol. 82, no. 5, pp. 56–65).

Gordon Beckhorn

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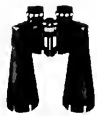

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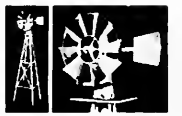

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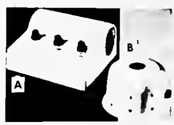

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For those who received new cameras for Christmas, for those who are restless to get outdoors with their old ones, and for all whose files are brimming over with beautiful pictures, *Natural History* joyfully announces another chance to try your luck: the photo contest is on again.

This year we have included black-and-white photography, kept the theme broad, and opened separate categories for those with specialized techniques. We have altered the rules a bit, juggled the judges, and changed the prizes. So read on.

The Categories: 1. The Natural World, including Man. 2. Macro- and Micro-photographs, including scanning electron micrographs. 3. A Chronological Sequence, which may be up to five photographs, of an "Event in Nature."

The Rules: The competition is open to everyone except employees of The American Museum of Natural History and their kin and all previous winners. 2. Competitors may submit up to three previously unpublished entries in each category. 3. Entries may be transparencies or prints up to 8" by 10". Each entry must contain the name and address of the photographer and the category. 4. For each entry, please tell us the camera model used. 5. Include a self-addressed, stamped envelope since we want to return your pictures to you.

The Closing Date: All entries should be postmarked no later than April 1, 1976.

The Rewards: Grand Prize is $500. First prize for each category is $250. Ten Honorable Mentions will receive $100 each.

More Rewards: All winning entries will be published in a special, picture-filled issue of *Natural History.*

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Pack your beautiful entries carefully and mail them to:
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Announcements

A special program honoring **Black History Week** has been scheduled for the People Center, second floor of The American Museum of Natural History, from February 9 through February 15. This program, planned by the African-American Studies Group of the Museum's Department of Education, will focus on the culture and history of people of African descent. Detailed information can be obtained at Museum information desks.

On Saturday, February 14, at 11:00 A.M., Jack Adams will appear as **Merlin,** the ancient wizard of King Arthur's court, in a children's program in the main Auditorium of the Museum. This theater-concert performance will chronicle the quirks of human behavior with rich humor and unequaled magical happenings.

On Saturday, February 28, at 11:00 A.M., **The Hidden World** will be shown in the main Auditorium of the Museum. This color film by Campbell Norsgaard explores the world of insects. This program is free to Family, Supporting, Donor, and Centennial Members. Admission for all others is $1 for adults and 25¢ for children.

The Netsilik Eskimos, the first of four programs in the series **Habitat: Housing and Shelter for the Peoples of the World,** will be shown on Thursday, February 19, at 7:30 P.M., in the main Auditorium of the Museum. This film shows the construction of both individual and community igloos and gives a glimpse of Eskimo life-style along the frozen Arctic coast northwest of Hudson's Bay. Dr. Asen Balikci, an associate professor of anthropology at the University of Montreal and the ethnographer in charge of the Netsilik Eskimo film project, will introduce and comment on his film and answer questions. No fee for Family, Supporting, Donor, and Centennial Members. Fee for all others is $10 for the series; $3 for each program.

Buckminster Fuller, the noted architect, philosopher, visionary, and multimedia thinker, will speak at the Museum, Sunday, February 22, at 3:00 P.M. His topic will be "Humans in the Universe." Advance tickets can be purchased at the Museum information desks. Admission is $2.50 for members; $3.50 for non-members.

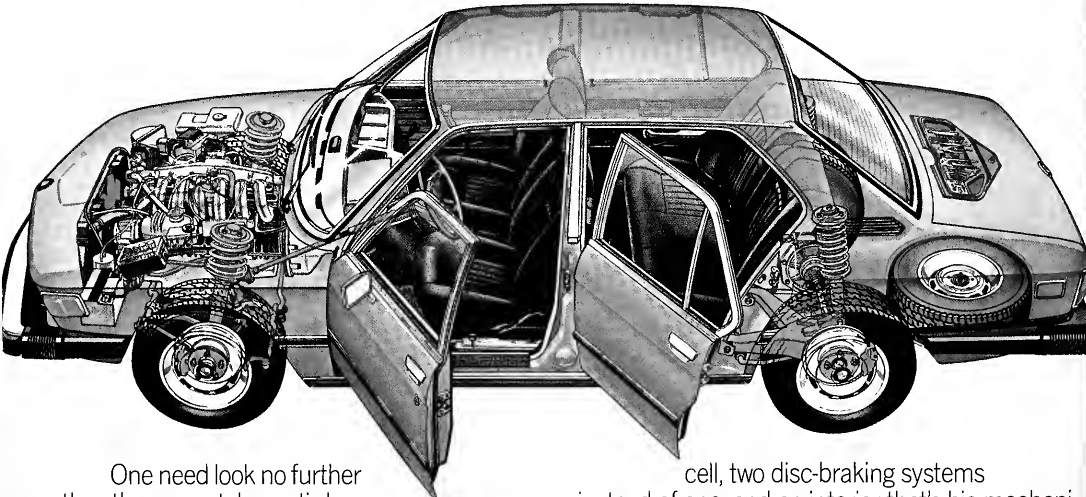
Beginning February 22 and March 6, the following **Weekend Workshops for Young People** will be offered by the Museum's Department of Education: Understanding Animal Behavior; Exploring with the Microscope; Introduction to Photography; Exploring Archeology; Banner Making with Animal Forms; Sharks; and Fangs, Scales, Shells, and Skin. For complete information, call 873-7507.

Beginning February 10 the Museum's Department of Education will offer the following **Programs for Adults** in the social and natural sciences: Archeology of Ancient Greece; The World of Birds; Anthropology Through Films; Social Behavior of Animals; New York's Past One Billion Years; Plants of the Wetlands; and An Awakening in Anthropology. For information on registration, dates, and fees call 873-7507.

Bookings are still available for the **Museum's June 1976 Cruise** to Turkey, the Black Sea, Bulgaria, Romania, the USSR, and the Greek Islands. Dr. Thomas D. Nicholson, the Museum's director, will be the cruise leader and will conduct informal star study sessions. Dr. Francois Vuilleumier will identify and describe the region's birdlife. For full details write to the Museum.

At the **Hayden Planetarium** of the Museum, "The Final Frontier" continues through April 5. This Sky Show takes us on a futuristic voyage to the outer reaches of space aboard the nuclear-propelled spacecraft *Eratosthenes.* On this trip, the ship encounters strange planets, double stars, stellar novae, other galaxies, neutron stars, and mysterious black holes. Shows begin at 2:00 P.M. and 3:00 P.M. during the week, with more frequent showings on weekends. Admission is $1.75 for adults; $1.00 for children.

The BMW 530i. An engineer's conception of a luxury car, not an interior decorator's.



One need look no further than the nearest domestic luxury sedan to find ample evidence of a styling department run rampant.

Brocade upholstery, opera windows, cabriolet tops, distinctive hood ornaments, etc., etc., etc.

Yet, underneath all this opulence, one generally finds that the average luxury car is indeed a very average car.

At the Bavarian Motor Works, it is our contention that, although the pursuit of luxury is no vice, when all is said and done, it is extraordinary performance that makes an expensive car worth the money.

So, while the BMW 530i features a rather lengthy list of refined luxuries, it also features a singularly responsive 3-liter, fuel-injected engine that never fails to astound even the experts with its smooth, turbine-like performance.

It features an uncanny four-wheel independent suspension system—McPherson struts in front and semi-trailing arms in the rear—that allows each wheel to adapt itself instantly to every driving situation, smoothly and precisely. Giving you a total control that will spoil you for any other car.

It features a solid steel passenger safety cell, two disc-braking systems instead of one, and an interior that's bio-mechanically engineered to prevent driver fatigue. Each seat in the 530i has an orthopedically molded shape. All controls are within easy reach. And all instruments are clear and visible.

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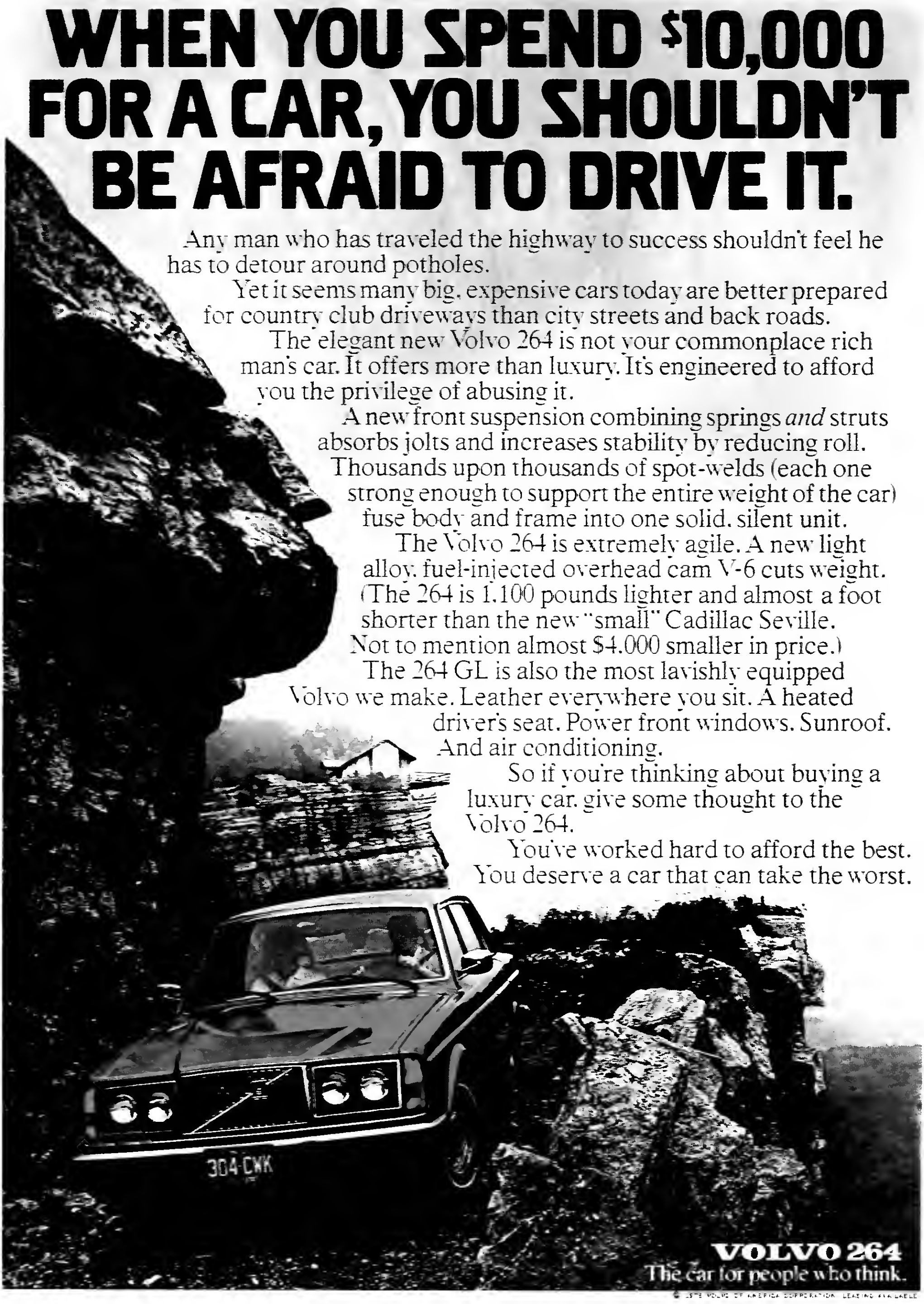
NATURAL HISTORY

MARCH 1976 · $1.25


WHEN YOU SPEND $10,000 FOR A CAR, YOU SHOULDN'T BE AFRAID TO DRIVE IT.
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VOLVO 264
The car for people who think.

NATURAL HISTORY

Incorporating Nature Magazine
Vol. LXXXV, No. 3
March 1976

The American Museum of Natural History
Robert G. Goelet, President
Thomas D. Nicholson, Director

Cover: *The Weddell seal's capabilities and physiology have been well studied in its natural environment. This inhabitant of the Antarctic can dive to nearly 2,000 feet, stay submerged for more than an hour, and surface rapidly without any ill effects. Photograph by Carleton Ray. Story on page 36.*

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Authors

The discovery that trees rake moisture from fog and clouds came more or less accidentally to **Hubert W. Vogelmann.** Professor of botany at the University of Vermont, Vogelmann has spent the past decade studying the fragile ecosystems of Vermont's alpine areas. In analyzing the water content of such areas, he noticed that more moisture collected in forests than in clearings. This knowledge led to a year's investigation of the moisture-gathering capacity of the remaining cloud forests of eastern Mexico. Vogelmann's nonprofessional activities include skiing, fishing, and raising enough food on his Vermont farm to be self-sufficient.

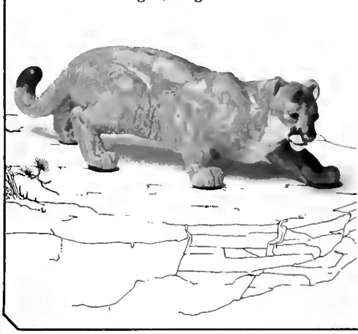
A lifelong regard for dairy cattle and concern for how people adapt to difficult environments led **Eugenia Shanklin** to choose the isolated farming area of County Donegal, Ireland, as the field site for her doctoral research in anthropology. In particular, she was studying livestock production, traditional attitudes toward raising cows and sheep, and the conversion of bogs into agriculturally productive land. On receiving her degree from Columbia University in 1973, Shanklin began to teach at Trenton State College in New Jersey, where she is assistant professor of anthropology.

"When in the presence of the emperor penguin in its natural surroundings, I am always struck by the majesty of the place and the animal," says **Gerald L. Kooyman,** who has made eight field trips to Antarctica to study this bird and other animals native to the continent. Kooyman—an experienced scuba diver—received his Ph. D. in zoology and is an associate research physiologist at Scripps Institution of Oceanography in La Jolla, California. His specialty is the structure and function of the respiratory systems of aquatic vertebrates and their diving behavior. His effort is "to understand animals that spend most or all of their lives in a medium a thousand times more dense than ours."

Polar Bear, length 8½"

Texas Ocelot, length 7"

Banded Seal, length 7"



Cougar, length 8½"

Grizzly Bear, length 7"

Black-footed Ferret, length 5½"

Announcing the Friends Of The Earth Collection of American Wildlife

In the tiny Swedish town of Gantofta, a noted sculptor-naturalist named Maria Ericson is creating a menagerie of stoneware animals. Her art pays tribute to the wildlife she loves and knows so well.

Each sculpture is cast, finished, and glazed by hand under her watchful eye. If she's pleased with the piece, her name goes on it. If not, it's broken and returned to the earth. The process is exacting and slow; only 200 of these pieces are signed each month.

This work was commissioned by Friends of the Earth, a non-profit group that fights for legislation to protect our natural resources. For example, we helped persuade the government to declare the grizzly a threatened species last year; fewer than 1,000 are left. Now we're working to create the Great Bear Wilderness Sanctuary in Montana to insure the survival of this noble species.

Friends of the Earth saved the banded seal by guiding through Congress the Marine Mammal Protection Act of 1972. Now we want to preserve the shrinking habitats of the ocelot, which is endangered, and the cougar. By pressing for controls on the use of lethal pesticides, we're helping the endangered black-footed ferret to survive. And we're monitoring Alaskan oilfields lest the polar bear's fragile environment be destroyed.

To help fund such projects, we're offering the first six in the series of signed sculptures created exclusively for us by Maria Ericson. While some special editions such as this have a remarkable history of appreciation (a Danish collector's plate which sold for $10 in 1969, now commands $245!), each purchase you make directly benefits Friends of the Earth. In addition, you automatically become an Introductory Member and receive *Not Man Apart*, a biweekly newspaper in the front line of the fight to save our natural resources.

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Sirs: Please send me the following at $37 each plus $2 handling (or, 3 for $100 + $3; or 6 for $200 + $5) [CT residents add 7% tax] and confirm my membership in Friends of the Earth:

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___banded seal(s) ___polar bear(s)
___grizzly bear(s) ___cougar(s)

I must be satisfied or I may return my purchase in 30 days for full refund and cancel my membership.

Enclosed find $____ check or money order. Or, charge ☐ BankAmericard ☐ Master Charge. Interbank #______

Acc't # __________ Exp._____

Signature ________________

Name ________________

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City/State/ZIP ________________

National 4-H Forestry Award winners, front to rear: Jeffrey Little, John Pfleiderer, Melinda Hadden, Craig Jerabek, Steve Welches, and David Doherty, Jr.

How six 4-H members became the proud parents of over 60,000 baby trees

In the year 2000, Americans will use about twice as much paper and wood products as they use today. And the U.S. Forest Service predicts that America's commercial timberlands won't be able to keep up with the demand.

Our hope lies to a great extent in concerned *young* people—like these six teen-agers who won the National 4-H Forestry Award and scholarship. These young people show just what can be accomplished. And that's why we're sponsoring the awards: to encourage people to start young—thinking about the future of America's forests and doing something about it.

Enough trees to keep a city going

Together, Craig Jerabek, David Doherty, and Jeffrey Little planted over 57,000 of the 60,000 seedlings—enough to keep a city of 16,000 people supplied in paper for an entire year when the trees are grown.

Melinda Hadden's specialty is *Christmas* trees—she's planted 1,200 of them. She's also planted about 300 trees for homeowners whose trees were destroyed by a violent windstorm.

John Pfleiderer has researched and fought Dutch elm disease—a killer which wiped out many of Greeley, Colorado's most beautiful trees. (John also taught himself grafting—and created new forms of trees.)

But there's more to a forest than just trees. Healthy forests are a complete ecosystem. That's why Steve Welches has planted over 1,200 shrubs for animal cover. And why David Doherty has built dens and brush piles for rabbits and small game birds. (And succeeded in bringing them back to land that was once ravaged by Hurricane Camille.)

Fortunately, these six teen-agers aren't alone in their commitment. There are 100,000 *more* 4-H members also working in forestry.

And forest companies pulling on the same team.

International Paper shares the burden

We've developed a Supertree—a southern pine that grows taller, straighter, healthier, and faster than ordinary pines.

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More to be done

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At International Paper, we believe forest products companies, private landowners and government should work together to develop more constructive policies for managing America's forests. The wrong policies can make tree farming impossible and force the sale of forest land for other purposes. The right policies can assure continuation of America's forests—a renewable natural resource.

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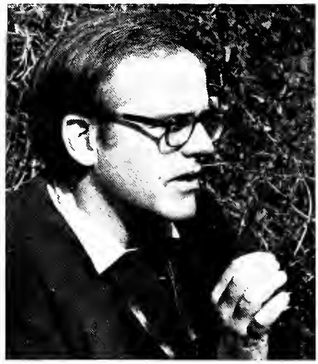

Robert S.O. Harding and **Shirley C. Strum** consider their study of the baboons in Gilgil, Kenya, a rare opportunity to observe evolving behavior in a stable, free-ranging primate population. They both plan to continue their work there. Harding, who teaches anthropology at the University of Pennsylvania, will concentrate on the baboons' ecology. Strum, an anthropologist at the University of California at San Diego, will go on with her investigation of the baboons' social organization. Harding became interested in animal behavior while working for the State Department in Germany, a career he followed until 1967. Strum first became interested in primates because she thought people were too complicated. She now finds that her interest in humanity has been rekindled.

An authority on Arctic art and culture, but with a wide-ranging interest in other regions as well, **Edmund Carpenter** has lived and worked among Indian and Eskimo societies for many years. He is the author of *Eskimo Realities* and is now preparing a book on the treasures of Klukwan, a center of the art of Northwest Coast Indians. Carpenter, who has taught anthropology at several universities in the United States and Canada, is currently associated with the Museum für Völkerkunde at Basel, Switzerland. The photograph of Carpenter was taken during the Hindu spring festival in Benares, India, when his face was painted with grease by other participants. **William Reid,** who wrote the prologue to Carpenter's article, is a carver whose work, including a house with totems and mortuaries done for the University of British Columbia, continues the tradition of his Haida Indian forebears.

An Inadvertent Ecologist

Louis Pasteur foresaw an area of science that is only now developing

To view Louis Pasteur's professional achievements gives one the impression that he led an enchanted life. His contributions to science, technology, and medicine were prodigious and continued without interruption from his early twenties to his mid-sixties. His skill in public debates and his flair for dramatic demonstrations enabled him to triumph over his opponents. His discoveries had practical applications that immediately contributed to the health and wealth of humankind. His worldwide fame made him a legendary character during his lifetime; he was, and remains, the white knight of science.

While writing Pasteur's biography a quarter of a century ago, I could readily document the fact that his extraordinary successes had been achieved at the cost of immense labor and against tremendous odds—including the stroke that paralyzed him on the left side at the age of forty-six. However, I felt I could also read between the lines of his public statements the frequent expressions of a melancholy mood, an intellectual and emotional regret at having sacrificed great theoretical problems to the pursuit of practical applications. Writing as if he had not been complete master of his own life, Pasteur stated time and time again that he had been "enchained" by the inescapable logic of his discoveries; he had thus been compelled to move from the study of crystals to fermentation, then to spontaneous generation, on to infection and vaccination.

One can indeed recognize a majestic ordering in Pasteur's scientific career. Yet, the logic that governed the succession of his achievements was not as inescapable as he stated. At almost any point in the evolution of his scientific career, he could have followed, just as logically, other lines of work that would have led him to discoveries in fields other than fermentation and vaccination. Some of his casual remarks indicate that he was aware of the potentialities he had left undeveloped.

Early in his scientific life he predicted, for example, that a day would come "when microbes will be utilized in certain industrial operations on account of their ability to attack organic matter." Today, in fact, microbial processes are used on an enormous scale to produce organic acids, solvents, vitamins, enzymes, and drugs. In 1877, he observed that the anthrax bacillus loses its virulence when placed in contact with certain soil microbes and he suggested that saprophytic organisms might be used to combat infectious agents. This was of course a vision of antibiotic therapy, more than sixty years before its actual beginning. Such lines of investigation, and others that he suggested, were within Pasteur's technical possibilities and he could have followed them, if he had had time. He had good reasons indeed to ask himself whether "the road not taken" might not have been the better road.

Many other aspects of his early scientific work continued to occupy his mind throughout his life and frequently surfaced in the form of casual remarks, suggestions for new lines of experiments, and prophetic views on the direction science should take.

The effect of environmental factors on the characteristics and activities of living things was a particular theme that he did not develop in his experimental work but that continually emerged in his writings. Here again one of his statements betrays regret at his not having followed his early hunches. He had entered the field of pathology almost by accident through his work on the diseases of silkworms. His first hypothesis had been that these diseases were nutritional and physiological in nature, but he eventually discovered that they could be controlled by protecting the worms against microbial contamination. However, despite the outstanding success of this control technique, he continued to believe that the resistance of the worms could be increased by measures that would improve their physiological state. In *Etudes sur la maladie des vers à soie,* he went as far as to state: "If I were to undertake new studies on the silkworm diseases, I would direct my effort to the environmental conditions that increase their vigor and resistance." This phrase clearly reveals an aspect of his thought that greatly intrigued him but that he did not have the time to convert into experimental work.

Even though Pasteur's name is identified with the "germ theory" of fermentation and disease—namely, the view that many types of chemical alterations and of pathological processes are caused by specific types of microbes—it is certain that his concern was not limited to the causative role of microbes. He was intensely interested in what he called the "terrain," a word he used to include the environmental factors that affect the course of fermentation and of disease. I now see more clearly than I did when writing Pasteur's biography that the magnitude of his theoretical and practical achievements derives in large part from the fact that his conceptual view of life was fundamentally ecological.

From the very beginning of his biological investigations, Pasteur became aware of the fact that the chemical activities of microbes are profoundly influenced by environmental factors. Furthermore, he developed very early a sweeping ecological concept of the role played by microbial life in the cycles of matter. During the 1860s he wrote letters to important French officials to advocate support of microbiological sciences on the

grounds that the whole economy of nature, and therefore man's welfare, depended upon the beneficial activities of microorganisms. He boldly postulated that microbial life is responsible for the constant recycling of chemical substances under natural conditions—from complex organic matter to simple molecules and back into living substance. In a language that was more visionary than scientific, he asserted that each of the various microbial types plays a specialized part in the orderly succession of changes essential for the continuation of life on earth. Long before the word ecology had been introduced into the scientific literature, he thus achieved an intuitive understanding of the interplay between biological and chemical processes that brings about the finely orchestrated manifestations of life and of transformations of matter in natural phenomena.

Pasteur's ecological attitude can also be recognized in his repeated emphasis—to the point of obsession—on the fact that the morphology and chemical activities of any particular microbial species are conditioned by the physicochemical characteristics of the environment. He pointed out, for example, that molds can be filamentous or yeastlike in shape, depending upon the oxygen tension of the medium in which they grow. He demonstrated also that the gaseous environment determines the relative proportions of alcohol, organic acids, carbon dioxide, and protoplasmic material produced by a particular microbial species from a particular substrate. Observations of this type give to the book in which he assembled his studies on beer (*Etudes sur la bière,* published in 1876) an importance that far transcends the practice of beer making. In that book he approached the problem of fermentation from an ecological point of view. By demonstrating that "fermentation is life without oxygen," he introduced the first sophisticated evidence of biochemical mechanisms in an ecological relationship.

The sophistication of his ecological attitude is perhaps best illustrated by his studies of butyric fermentation and of putrefaction. He noticed that the bacteria that produce butyric acid can function only in the absence of oxygen. When he observed these microbes under the microscope, for example, he noticed that they were actively motile in the center of a drop of fermenting fluid but lost their motility at the margin of the drop where they were in direct contact with the air; he showed indeed that he could arrest butyric acid production simply by passing a current of air through the fermenting fluid. He established also that the evil-smelling decomposition (putrefaction) of meat or other products containing proteins was caused by microbes that functioned only when protected from the air.

The ecological attitude in Pasteur's laboratory certainly helped his associate Emile Duclaux, who eventually became director of the Pasteur Institute, to recognize that the enzymatic equipment of microbes can be modified at will by altering the composition of the culture medium. This was the first demonstration of a phenomenon that opened the way for discoveries on enzyme induction, and thus constitutes another fundamental link in the understanding of the ecological relation between environmental factors and biological characteristics.

Pasteur's recognition of the effects that environmental factors exert on metabolic activities is now incorporated into theoretical microbiology and technological applications. In contrast, his forceful statements concerning the importance of the terrain in infectious diseases have been overlooked, in part because he did not have time to support his intuitive views by systematic laboratory investigations, and perhaps even more because medical scientists continue to neglect this field, except with regard to the special approach that Pasteur himself had opened—immunological protection. Yet he had a sophisticated ecological concept of infectious processes based on an awareness of the genetic and environmental parameters that condition evolutionary and phenotypic adaptations. This aspect of his biological philosophy can be illustrated with statements paraphrased from his writings.

Early in his work on disease, Pasteur recognized that it was a biological necessity for living things to be endowed with natural resistance to the agents of destruction ubiquitous in their environment. As he saw it, populations, of microbes or of men, usually achieve some sort of evolutionary adaptation to their environment that renders them better able to resist the causes of disease with which they often come into contact.

Furthermore, he took it for granted that the body in a state of normal physiological health exhibits a striking resistance to many types of microbial agents. As he pointed out, the body surfaces harbor various microorganisms that can cause damage only when the body is weakened. In contrast, infection often fails to take hold even when antiseptic measures are neglected in the course of surgery. Indeed, humans possess a remarkable ability to overcome foci of infection.

Pasteur's attitude regarding the importance of physiological well-being in resistance to infection had developed during his studies with silkworms. He had soon recognized profound differences in the pathogenesis of two diseases in these insects. In one, pébrine, the presence of the specific protozoan was a sufficient cause of the disease, provided the infective dose was large enough. In the other, flacherie, the resistance of the worms to infection was profoundly influenced by environmental factors. Among these, Pasteur considered that excessive heat and humidity, inadequate aeration, stormy weather, and poor food were inimical to the general physiological health of the insects. As he put it, the proliferation of microorganisms in the intestinal tract of worms suffering from flacherie was more an effect than a cause of the disease. Here Pasteur was anticipating George Bernard Shaw's remark in the preface to *The Doctor's Dilemma* (1906): "The characteristic microbe of a disease might be a symptom instead of a cause."

Pasteur did not hesitate to extend these views to the most important human diseases. He accepted that resistance to tuberculosis was on the one hand an expression of hereditary endowment and on the other hand was influenced by the state of nutrition and by certain factors of the environment, including the climate.

In his words: "A child is not likely to die of tuberculosis if he is raised under good nutritional and climatic conditions. . . . Let me emphasize that there is a fundamental difference between the characteristics that define a disease—the disease *per se* so to speak—and the set of circumstances that increase susceptibility to it. . . . There may be more similarity than appears at first sight between the factors that favor pulmonary tuberculosis and those that are responsible for the spread of the *flacherie* disease among silkworms."

Again in his words: "All too often, the general condition of a person who has been wounded, his physiological

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misery, his poor mental state, are responsible for the fact that his body cannot offer an adequate resistance to the multiplication of microbes in the wound.''

This point of view naturally led Pasteur to conclude that resistance to infection could probably be increased by improving the physiological state of the infected individual. He urged his collaborator Emile Duclaux to look for procedures that would increase the general resistance of silkworms. And he expressed the opinion that in man also, successful therapy often depends upon the ability of the physician to restore the physiological conditions favorable to natural resistance.

Although Pasteur thus had a clear view of the influence that the physiological state and environmental factors exert on resistance to infection, he did not carry out any significant experimental work in this area. He probably felt that in the state of scientific knowledge of his time the more urgent task was to determine the specific causes of infection and to search for specific methods of protection. It is indeed certain that biological sciences in general and microbiological sciences in particular could not have gone far without the precise knowledge and the intellectual discipline provided by the concept of specificity. The time has come, however, when it would be profitable to follow more actively the other approaches that Pasteur visualized but did not follow—the physiological and ecological study of microorganisms in natural systems and in pathological processes.

Pasteur's ecological philosophy had little influence on the practical policies he advocated for controlling the phenomena of fermentation and infection. When he discussed large theoretical problems in the light of ecological concepts, he professed that the activities of microbes are essential for the continuation of life on earth; he also suggested that microbes might safely coexist with animals and human beings if the infectious process took place under proper environmental and physiological conditions. In practice, however, he devoted most of his laboratory work to the development of practical techniques for the domestication or destruction of microbes. This dichotomy between conceptual theory and scientific practice can be partially explained by the climate of scientific and public opinion in the nineteenth century.

The germ theory was formulated at a time when many biologists and social philosophers believed that one of the fundamental laws of life is competition, a belief symbolized by phrases such as ''nature red in tooth and claw'' and ''survival of the fittest.'' The ability of an organism to destroy or at least to master its enemies or competitors was then deemed an essential condition of biological success. In the light of this theory, microbes were to be destroyed, unless they could be used for some human purpose, as in desirable fermentations. Aggressive warfare against microbes was particularly the battle cry of medical microbiology and is still reflected in the language of this science. The microbe is said to be an ''aggressor'' that ''invades'' the tissues; the body ''mobilizes'' its defenses; the physician or the scientist is a disease ''fighter'' whose goal is to achieve the ''conquest'' of this or that infection.

As we have seen, Pasteur did not share the simple-minded view that killing and being killed are the only alternatives in biological relationships; indeed he had perceived the ecological possibilities and advantages of peaceful coexistence. But he lived in a period when knowledge meant power used for the conquest of nature. It was during the nineteenth century that the findings of experimental science were for the first time converted into large-scale technological applications. Like his contemporaries, Pasteur identified progress with the use of science for achieving mastery over natural forces. As he was very much a man of his time, he focused most of his effort on the kind of scientific problems most likely to yield results of practical significance—for example, by helping in the ''control'' of fermentation and in the ''conquest'' of disease. For his public life, scientific progress meant the development of techniques such as sterilization, pasteurization, and vaccination, even though these practical lines of work prevented him from pursuing other questions that he considered of larger theoretical significance.

Scientists, like artists, unavoidably reflect the characteristics of the civilization and the time in which they live. In this sense, they are ''enchained,'' as Pasteur complained he had been, by the inexorable logic of their time and their work. A few of the greater ones, however, have visions that appear to be without roots in their cultural past and that are not readily explained by direct environmental influences. These visionaries appear indeed almost as eruptive phenomena, seemingly unpredictable from their environment. Yet even they are not freaks in the natural sequence of cultural events. They constitute mentalities through which emerge and become manifest social undercurrents that remain hidden to less perceptive minds. Some of these visionaries succeed in converting their preoccupations—which are signs from the cultural subconscious—into messages and products of immediate value to their fellowmen; they become the heroes of their societies. Others perceive the hopes and the tasks of the distant future, but without providing definite answers or practical solutions; they give warnings of the questions and problems to come, but their anticipations are usually not understood by their contemporaries.

Pasteur, however, belongs in both classes. As a representative of nineteenth-century bourgeois civilization, he focused much of his scientific life on the practical problems of his time. But he was also a visionary who saw beyond the needs and concerns of his contemporaries; he formulated scientific and philosophical problems that were not yet ripe for solution.

His immense practical skill in converting theoretical knowledge into technological processes made him one of the most effective men of his century; he synthesized the known facts of biology and chemistry into original concepts of fermentation and disease and thus created a new science that dealt with the urgent needs of his social environment. The other side of his genius, although less obvious, is more original and perhaps more important in the long run. His emphasis on the essential role played by microorganisms in the economy of nature, and on the interplay between living things and environment, made him perceive an area of science that is only now beginning to develop; he contributed to scientific philosophy by perceiving that all forms of life are integrated components of a global ecological system.

René Dubos, professor emeritus at The Rockefeller University in New York City, is a microbiologist and experimental pathologist.

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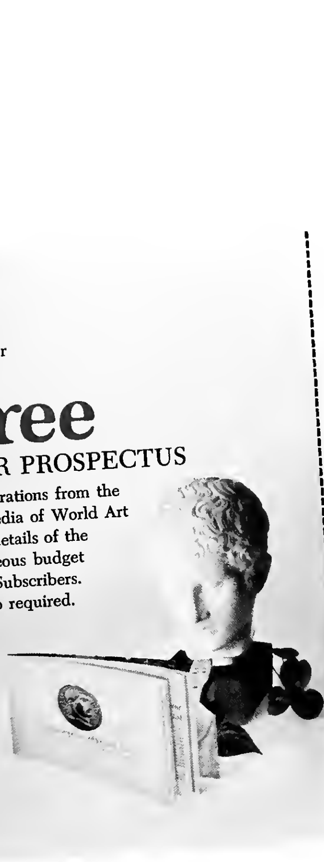

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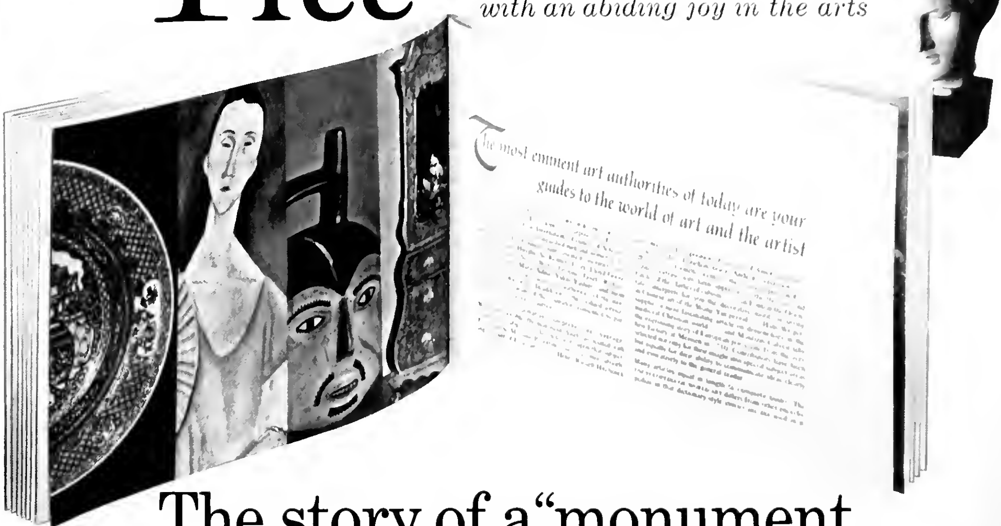

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Criminal Man Revived

Despite its weak plot, this old—and dangerous—farce keeps reappearing

W.S. Gilbert directed his potent satire at all forms of pretension as he saw them. For the most part we continue to applaud him: pompous peers and affected poets are still legitimate targets. But Gilbert was a comfortable Victorian at heart, and much that he labeled as pretentious now strikes us as enlightened—higher education for women, in particular.

> A women's college! maddest folly going!
> What can girls learn within its walls worth knowing?

In *Princess Ida,* the Professor of Humanities at Castle Adament provides a biological justification for her proposition that "man is nature's sole mistake." She tells the tale of an ape who loved a beautiful woman. To win her affection, he tried to dress and act like a gentleman, but all necessarily in vain, for

> Darwinian Man, though well-behaved,
> At best is only a monkey shaved!

Gilbert produced *Princess Ida* in 1884, eight years after an Italian physician, Cesare Lombroso, had initiated one of the most powerful social movements of his time with a similar claim made in all seriousness about a group of men—born criminals are essentially apes living in our midst. Later in life, Lombroso recalled his moment of revelation:

> In 1870 I was carrying on for several months researches in the prisons and asylums of Pavia upon cadavers and living persons, in order to determine upon substantial differences between the insane and criminals, without succeeding very well. Suddenly, the morning of a gloomy day in December, I found in the skull of a brigand a very long series of atavistic anomalies. . . . The problem of the nature and of the origin of the criminal seemed to me resolved; the characters of primitive men and of inferior animals must be reproduced in our times.

Biological theories of criminality were not new, but Lombroso gave the argument a novel, evolutionary twist. Born criminals are not simply deranged or diseased; they are, literally, throwbacks to a previous evolutionary stage. The hereditary characters of our primitive and apish ancestors remain in our genetic repertoire. Some unfortunate men are born with an unusually large number of these ancestral characters. Their behavior may have been appropriate in savage societies of the past; today, we brand it as criminal. We may pity the born criminal, for he cannot help himself; but we cannot tolerate his actions. (Lombroso believed that about 40 percent of criminals fell into this category of innate biology—born criminals. Others committed misdeeds for greed, jealousy, extreme anger, and so on—criminals of occasion.)

I tell this tale for three reasons that combine to make it far more than an antiquarian exercise in a small corner of forgotten, late-nineteenth-century history.

1. A generalization about social history: It illustrates the enormous influence of evolutionary theory in fields far removed from its biological core. Even the most abstract scientists are not free agents. Major ideas have remarkably subtle and far-ranging extensions. The inhabitants of a nuclear world should know this perfectly well, but many scientists have yet to get the message.

2. A political point: Appeals to innate biology for the explanation of human behavior have often been advanced in the name of enlightenment. The proponents of biological determinism argue that science can cut through a web of superstition and sentimentalism to instruct us about our true nature. But their claims have always had a different primary effect: they are used by the leaders of class-stratified societies to assert that a current social order must prevail because it is the law of nature. Of course, no view should be rejected because we dislike its implications. Truth, as we understand it, must be the primary criterion. But the claims of determinists have always turned out to be prejudiced rubbish, not ascertained fact—and Lombroso's criminal anthropology is the finest example I know. Biological determinism is a dangerous game for liberals (and a godsend for conservatives and apologists for the status quo).

3. A contemporary note: Lombroso's brand of criminal anthropology is dead, but its basic postulate lives on in popular notions of criminal genes or chromosomes. These modern incarnations are worth about as much as Lombroso's original version. Their hold on our attention only illustrates the unfortunate appeal of biological determinism in our continuing attempt to exonerate a society in which most of us flourish by blaming the victim.

This year marks the centenary of Lombroso's founding document—later enlarged into the famous *L'uomo delinquente* (*Criminal Man*). Lombroso begins with a series of anecdotes to assert that the usual behavior of lower animals is criminal by our standards. Animals murder to suppress revolts; they eliminate sexual rivals; they kill from rage (an ant, made impatient by a recalcitrant aphid, killed and devoured it); they form criminal associations (three communal beavers shared a territory with a solitary individual; the trio visited their neighbor and were well treated; when the loner returned the visit, he was killed for his solicitude). Lombroso even brands the fly catching of insectivorous plants as an "equivalent of crime" (although I fail to see how it differs from any other form of eating).

In the next section, Lombroso examines the anatomy of criminals and finds the physical signs (stigmata) of their primitive status as throwbacks to our evolutionary past. Since he has

already defined the normal behavior of animals as criminal, the actions of these living primitives derives from their nature. The apish features of born criminals include relatively long arms, prehensile feet with mobile big toes, low and narrow forehead, large ears, thick skull, large and prognathous jaw, copious hair on the male chest, and diminished sensitivity to pain. But the throwbacks do not stop at the primate level. Large canine teeth and a flat palate recall a more distant mammalian past. Lombroso even compares the heightened facial asymmetry of born criminals with the normal condition of flatfishes (both eyes on one side of the head)!

But the stigmata are not only physical. The social behavior of the born criminal also allies him with apes and living human savages. Lombroso placed special emphasis on tattooing, a common practice among primitive tribes and European criminals. He produced voluminous statistics on the content of criminal tattoos and found them lewd, lawless, or exculpating (although he had to admit one read: *Vive la France et les pommes de terres frites*—"long live France and french fried potatoes"). In criminal slang, he found a language of its own, markedly similar to the speech of savage tribes in such features as onomatopoeia and personification of inanimate objects: "They speak differently because they feel differently; they speak like savages, because they are true savages in the midst of our brilliant European civilization."

Lombroso's theory was no work of abstract science. He founded and actively led an international school of "criminal anthropology" that spearheaded one of the most influential of late-nineteenth-century social movements. Lombroso's "positive," or "new," school campaigned vigorously for changes in law enforcement and penal practices. They regarded their improved criteria for the recognition of born criminals as a primary contribution to law enforcement. Lombroso even suggested a preventive criminology—society need not

wait (and suffer) for the act itself, for physical and social stigmata define the potential criminal. He can be identified (in early childhood), watched, and whisked away at the first manifestation of his irrevocable nature (Lombroso, a liberal, favored exile rather than death). Enrico Ferri, Lombroso's closest colleague, recommended that "tattooing, anthropometry, physiognomy . . . reflex activity, vasomotor reactions [criminals, he argued, do not blush], and the range of sight" be used as criteria of judgment by magistrates.

Criminal anthropologists also campaigned for a basic reform in penal practice. An antiquated Christian ethic held that criminals should be sentenced for their deeds, but biology declares that they should be judged by their nature. Fit the punishment to the criminal, not to the crime. Criminals of occasion, lacking the stigmata and capable of reform, should be jailed for the term necessary to secure their amendment. But born criminals were condemned by their nature: "Theoretical ethics passes over the diseased brain, as oil does over marble, without penetrating it." Lombroso recommended irrevocable detention for life (in pleasant, but isolated surroundings) for any recidivist with the telltale stigmata. Some of his colleagues were less generous. An influential jurist wrote to Lombroso:

> You have shown us fierce and lubricious orang-utans with human faces. It is evident that as such they cannot act otherwise. If they ravish, steal, and kill, it is by virtue of their own nature and their past, but there is all the more reason for destroying them when it has been proved that they will always remain orang-utans.

And Lombroso himself did not rule out the "final solution":

> The fact that there exist such beings as born criminals, organically fitted for evil, atavistic reproductions, not simply of savage men but even of the fiercest animals, far from making us more compassionate towards them, as has been maintained, steels us against all pity.

One other social impact of Lombroso's school should be mentioned. If human savages, like born criminals, retained apish traits, then primitive tribes—"lesser breeds without the law"—could be regarded as essentially criminal. Thus, criminal anthropology provided a powerful argument for racism and imperialism at the height of European colonial expansion. The same jurist who spoke so blithely of orangutans argued that modern European criminals would be "the ornament and moral aristocracy of a tribe of Red Indians." Lombroso, in noting a reduced sensitivity to pain among criminals, wrote:

> Their physical insensibility well recalls that of savage peoples who can bear in rites of puberty, tortures that a white man could never endure. All travelers know the indifference of Negroes and American savages to pain: the former cut their hands and laugh in order to avoid work; the latter, tied to the torture post, gaily sing the praises of their tribe while they are slowly burnt. [You can't beat a racist *a priori*. Think of how many Western heroes died bravely in excruciating pain—Saint Joan burned, Saint Sebastian transfixed with arrows, other martyrs racked, drawn, and quartered. But when an Indian fails to scream and beg for mercy, it can only mean that he doesn't feel the pain.]

If Lombroso and his colleagues had been a dedicated group of proto-Nazis, we could dismiss the whole phenomenon as a ploy of conscious demagogues. It would then convey no other message than a plea for vigilance against ideologues who misuse science. But the leaders of criminal anthropology were "enlightened" socialists and social democrats who viewed their theory as the spearhead for a rational, scientific society based on human realities. The genetic determination of criminal action, Lombroso argued, is simply the law of nature and of evolution:

> We are governed by silent laws which never cease to operate and which rule society with more authority than the laws inscribed on our statute books. Crime appears to be a natural phenomenon . . . like birth or death.

In retrospect, Lombroso's scientific "reality" turned out to be his social prejudice imposed before the fact upon a supposedly objective study. His notions condemned thousands of innocent people to a prejudgment that often worked as a self-fulfilling prophecy. His attempt to understand human behavior by mapping an innate potential displayed in our anatomy served only to work against social reform by placing all blame upon a criminal's inheritance.

Of course, no one takes the claims of Lombroso seriously today. His statistics were faulty beyond belief; only a blind faith in inevitable conclusions could have led to his fudging and finagling. Besides, no one would look to long arms and jutting jaws today as signs of inferiority; modern determinists seek a more fundamental marker in genes and chromosomes.

Much has happened in the 100 years between Lombroso's formulation of his theory and our Bicentennial celebrations. No serious advocate of innate criminality recommends the irrevocable detention or murder of the unfortunately afflicted or even claims that a natural penchant for criminal behavior necessarily leads to criminal action. Still, the spirit of Lombroso is very much with us. When Richard Speck murdered eight nurses in Chicago, his defense argued that he couldn't help it because he bore an extra Y chromosome. (Normal females have two X chromosomes, normal males an X and a Y. A small percentage of males have an extra Y chromosome, XYY.) This revelation inspired a rash of speculation; articles on the "criminal chromosome" inundated our popular magazines. The naïvely determinist argument had little going for it beyond the following: Males tend to be more aggressive than females; this may be genetic. If genetic, it must reside on the Y chromosome; anyone possessing two Y chromosomes has a double dose of aggressiveness and might incline to violence and criminality. But the hastily collected information on XYY males in prisons seems hopelessly ambiguous, and even Speck himself turns out to be an XY male after all. Once again, biological determinism makes a splash, creates a wave of discussion and cocktail party chatter, and then dissipates for want of evidence. Why are we so intrigued by hypotheses about innate disposition? Why do we wish to fob off responsibility for our violence and sexism upon our genes? The hallmark of humanity is not only our mental capacity but also our mental flexibility. We have made our world and we can change it.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

Announcements

Continuing through April in Gallery 77 of the Museum, **This Exhibit in Preparation** gives visitors a "behind the scenes" look at the techniques used to create the Museum's many marvelous dioramas and exhibits. Graphics, three-dimensional displays, and demonstrations by artists, taxidermists, preparators, and modelmakers reveal the inner workings of the Exhibition Department.

Beginning in early February, **The Chihuahua Whiptail Lizard** will be on view through mid-March in the Museum Showcase, Roosevelt Memorial Hall, at the main entrance of the Museum. This minipreview of the forthcoming Hall of Reptiles and Amphibians explains the fascinating subject of parthenogenesis.

Museum Fragrances may be enjoyed at all times in various exhibit halls: Aromas of grasslands in the Man in Africa Hall; of dry hayfields in the Asiatic Mammals Hall; of frangipani and salt air breezes in the Peoples of the Pacific Hall; and of conifers, earth, ferns, and dried and decaying leaves in the North American Forests Hall.

At the **Hayden Planetarium** of the Museum, "The Final Frontier" continues through April 5. This Sky Show takes us on a futuristic voyage to the outer reaches of space aboard the nuclear-propelled spacecraft *Eratosthenes*. On this trip, the ship encounters planets, double stars, stellar novae, other galaxies, neutron stars, and mysterious black holes. Shows begin at 2:00 P.M. and 3:00 P.M. during the week with more frequent showings on weekends. Admission is $1.75 for adults; $1.00 for children.

Crafts Week in New York will be celebrated in the Museum from March 16 through 19, between the hours of 1:30 and 4:00 P.M. An open crafts workshop will be held in the Louis Calder Laboratory, and a variety of craftspersons will give demonstrations in the People Center.

The 1976 Natural History Photography Competition

For those who received new cameras for Christmas, for those who are restless to get outdoors with their old ones, and for all whose files are brimming over with beautiful pictures, *Natural History* joyfully announces another chance to try your luck: the photo contest is on again.

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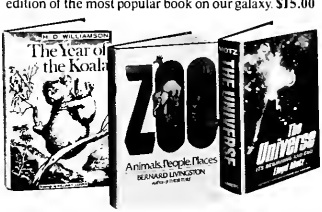

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Rain-making Forests

by Hubert W. Vogelmann

When fog and clouds swirl through mountain trees, they leave their moisture to irrigate the land

In about 25 B.C., Roman sailors visited the Canary Islands off North Africa, and upon their return to Mauretania, where they were headquartered, they related a remarkable story to the king, Juba II. It concerned a tree growing at the upper end of a ravine on one of the islands. During the night, the leaves and branches of this tree were able to gather water from the low-lying clouds that swept up the ravine. A cistern was built to store the water that collected underneath the tree, and so great was the tree's rain-making ability that it produced sufficient water for the whole island.

This tale may be an exaggeration but under the right conditions, trees do indeed comb moisture from clouds and fog and the condensation falls to the ground like rain. In mountainous regions where clouds frequently touch the summits or on coasts and islands where fog rolls in off the ocean, this phenomenon is common. On the rockbound coast of Maine, the moisture captured by solitary pines rooted in crevices allows patches of grass or moss to grow in the sandy soil around the tree trunks.

Moisture will stick to almost any object in its path. Beach strollers walking through a thick fog blowing in from the ocean soon find their clothing soaked. Mountain hikers become drenched when a cloud swirls about them. Springtime skiers experience the same thing when they ski through the dense fogs caused by the combination of warm spring air and wet snow.

Small droplets of moisture are too light to fall to the ground. Instead, they are carried along in air currents, where they are blown against the leaves and branches of trees. Collecting on the edges of the leaves and twigs, the tiny particles coalesce and grow, and when they are heavy enough, they fall to the ground like rain.

The high forests of the northeastern ranges, such as the Adirondacks or the Green or White Mountains, collect an impressive amount of water. These forests are dominated by spruces and firs, whose countless small needles and twiggy branches make up large surfaces—up to about 14 million yards per acre—that trap the water droplets from low-lying clouds. Dwight Leedy, a graduate student in botany at the University of Vermont, determined that in the Green Mountains at least five inches of water a year is combed from the clouds by the forests. In some areas of these forests, such as the mountain summits where the winds are strong, some thirty inches of water per year could be raked from the clouds and fog by the trees. These amounts of water would, of course, be added to the area's annual precipitation of between forty and sixty inches.

The mountain ranges of New England are by no means unique in their ability to comb moisture from fog and clouds. On one of the Hawaiian Islands, a rain gauge under a Norfolk Island pine tree showed that the tree collected thirty inches of water annually. And as another example, studies in the Bavarian Alps showed that the forests there produce 170 percent more water from fog than is provided by the annual rainfall.

Were it not for mountain forests, this additional moisture would never be available; it augments stream flows and percolates into the soil, eventually adding to groundwater supplies at lower elevations. Mountains are thus important aquifer recharge areas. Not only do they cause more rain to fall by forcing air upward, where it cools and releases its moisture, but their forests also collect fog moisture. Considering the importance of maintaining adequate water supplies today, it is essential to keep

Although broad-leaved trees, such as the ones in this Colombian rain forest, do not collect as much moisture as do coniferous trees, their destruction on mountainsides is decreasing the groundwater in tropical regions.

Hubert W. Vogelmann

Paul von Baich

As clouds and fog sweep through the forests of Rogers Pass in Glacier National Park, the myriad needles of the spruce and fir trees act like fine-toothed combs to capture the moisture, which then enters the groundwater supply.

our high mountain ecosystems intact.

Man, however, does not always understand the complexities of his environment. In his ecological ignorance, his alterations of the land have sometimes produced disastrous results. One such event took place in the mountains of southeastern Mexico north of Veracruz. Encouraged by the results of the fog- and cloud-moisture study in Vermont's mountains, I undertook a similar investigation in the Sierra Madre Oriental, where conditions for fog precipitation are ideal. Lush rain forests grow on the eastern slopes where moisture-laden winds sweep in from the Gulf of Mexico and deposit a hundred inches of water per year on the mountainsides. As the winds move westward, they are forced upward over the mountaintops, and the cooling air, which still holds some moisture, forms dense fogs that sweep inland over the dry high plateau that adjoins the westward side of the mountains. Dark, dripping forests once covered the eastern part of the plateau. But these flat, easily farmed lands were cleared long ago, turning most of the area into a bleak desert. Needing more land for their corn crops, farmers cut away the forests on the steep eastern side of the mountains. During the six-month-long dry seasons, however, this land now also dries out; trees that once caught the moisture there, even in the dry season, no longer being present. Now both the steep fields and those on the edge of the plateau grow only such plants as cactus and agave.

My study of much of this region indicated that even during the dry season there is a great deal of moisture in the air, but it is in the form of fog. With the cutting of the forests, the farmers destroyed one of their most important sources of water—the moisture that the trees had combed from the fog. Today the fog sweeps across barren ground and finally dissipates into the dry desert air. The removal of the forests has probably affected more than 1,000 square miles of this arid region. It is a classic example of man's lack of understanding his environment.

Some dry areas can perhaps be reclaimed by planting drought-resistant trees to prime the pump and start collecting fog moisture again. Fog-collecting screens could be used to gather water that would nourish the newly planted trees. And these once productive lands could probably become green again. □

Donegal's Lowly Sheep and Exalted Cows

by Eugenia Shanklin

"If you had the cow, you could live without the wife, but if you had not the cow, you would not be able to live at all"

The coast of southwest Donegal, Ireland, is one of the most beautiful and austere in the world and the interior of the region scarcely less so. The area resembles a high desert—windswept and barren except for an occasional tree bent in the direction of the prevailing winds. As a local priest put it, "When God was creating the earth, He had used up most of the fertile land by the time He got to Donegal and He had to save what He had left for America. So He compensated us by giving us all the scenery He had left over; we got cliffs rising out of the sea, high mountains, waterfalls, and white beaches, while the Europeans got the rich soil."

Such sentiments, however, are a privilege reserved for the tourist or for one who does not make his living from the land. It is difficult to find a Donegal farmer who appreciates either God's afterthoughts or the grandeur of the landscape.

Inland the dual impression of beauty and cruelty persists. The deep valleys are dotted with thatched cottages, with the thatch tied down against the gales, and cottages are not set at the top of hills but just beneath the crest. In addition, every stone, brae, and valley has a name and a legend, usually commemorating some murderous occasion. A study of the local place-ghosts reveals a long history of conquests and rebellions.

The land has been dominated in turn by chieftains, armies with holy causes, kings, absentee landlords, and today, by government bureaucrats. For two thousand years the population persisted while the conquerors came and went. Today, the command is progress; the goal, increased productivity. But the eventual result is no longer predictable, as traditional practices and innovative methods clash head on.

Although primitives and peasants alike are excoriated for their backward outlook and their reluctance to innovate, the effects of their strategies may in the long run conserve resources. While many traditional farming practices do provide low yields, only in the short-term view are such low yields considered "bad." If the people of southwest Donegal abandon their traditional practices, the resource conservation measures may be lost as well, ultimately leaving the area open to depopulation, either through degradation of resources or consolidation of holdings on a giant scale.

The area's resources are almost completely in the form of grazing land, mostly unimproved bog; this constitutes some 63 percent of all land available. No more than 2 to 3 percent of all land is good agricultural soil; some 10 percent is "improved," that is, has been reclaimed for agricultural purposes, such as growing potatoes, oats, and hay. Land reclamation involves a great deal of work but improvement shows spectacular results; boglands, for example, which in a virgin state carry one sheep per four acres, can be drained, fenced, and fertilized, making it possible to stock four sheep per acre. There are new techniques for reclaiming bogland, but these are effective only for sheep because the treatment of the bog surface renders it even more spongy than it is in its virgin state. Consequently, heavy cattle cannot negotiate the fields during any but the driest seasons of the year.

The climate is almost as poor as the soil. Gale-force winds, a growing season bounded more by rainfall than by temperature variations—with the heaviest rains coming during the harvest season—and extreme variation

Clifton Line

Paul Slaughter

Marked with paint for identification, sheep graze on the area's vast boglands. When drained and fertilized, this land can support more sheep, but Donegal farmers are not anxious to increase production.

Paul Slaughter


ugenia Shanklin

At the Donegal livestock mart, an auctioneer accepts bids while a handler walks the cow around to show it is not lame. These centers are replacing traditional cattle fairs, where sales involve lengthy, dramatic bargaining.

from year to year in both rainfall and duration of the frost-free season make the region a poor one for agricultural purposes.

Until 1922, Donegal was part of the historic province of Ulster, the northernmost province of Ireland, but in that year, Donegal was separated from what had been its traditional market and trade region and made part of the Republic of Ireland. The effect of this separation has been to isolate Donegal from its natural trade region, the interior of Ulster, and to force the people to rely on the south for most of their manufactured goods, as well as markets for their agricultural produce. The problems Donegal faces today result from its remoteness, its poor natural resources, and its intractable climate; the effect of these factors on the population has been a reduced standard of living compared to most parts of Ireland.

After many years of subsidizing the area, government policy has changed and the attempt now is to make the people economically self-sufficient, primarily by means of increased livestock production. Modern development plans also call for a shift in emphasis from cattle to sheep production. The traditional economy is a mixed one, based on cattle and sheep, with a strong emphasis on cattle production. Government subsidies for beef cattle have met favorable responses in the area, but similar subsidies for sheep and for land reclamation schemes intended to boost sheep production have not fared so well. The number of sheep has held constant or decreased slightly in some areas even while the subsidy rate has gone steadily up. In interviews, government officials explain this by pointing to the "prehistoric" mental outlook of the farmers and their refusal to adopt modern production methods.

The charges are not justified by the facts. Farmers produce cattle at higher returns than in other parts of Ireland; further, the mortality rate for cattle is lower in Donegal than in any other part of the country. Insofar as cattle production is concerned, then, whatever the farmers are doing seems to be successful, despite their so-called prehistoric bent.

Government officials find most offensive the refusal to increase sheep production. Residents base their refusal on the economic argument that cattle are more valuable than sheep—a cow is worth from $100 to $150, while the equivalent in sheep (five sheep eat as much as one cow) would be worth only about $65 to $85. The explanation does not suffice, however, because much of the land that might be reclaimed would be suitable only for sheep, and there is also strong resistance to reclamation projects. Nor does the economic argument suffice as an explanation for the distinctions that are made between the two kinds of animals, distinctions that are crucial to maintaining the long-term ecological balance.

The people of Donegal value their cows highly, a feeling that is perhaps best expressed in the literature:

"The cow is the hub of the household. You first have to get a wife, and then a cow. And the first thing you would have to look for in the wife would be if she was a good milker. You might get the cow as dowry with the wife, and could not do better, unless there was a bit of money as well. If you had the cow, you could live without the wife, but if you had not the cow, you would not be able to live at all."

The greater value placed on cows becomes apparent in the differential treatment of animals at livestock fairs. Most towns have a fair day once a month, when farmers bring in cattle and sheep for sale. Sheep can be sold anywhere in the town and are usually tied up in front of houses, shops, or any other convenient place. Cattle, however, must be sold on the "cattle hill," usually the highest spot in town, a grassy area set aside for this purpose alone.

Both cattle and sheep are driven into town early in the morning, but cattle must be sold by noon. Those that aren't are either taken home or removed to a fenced area and the hill is cleared. While on the hill, cattle are never hobbled or tied, and their owners watch over them while they graze. Sheep, however, are always tied and left standing until they are sold or until their owner emerges from the pub—whichever comes first. Sheep are usually cleared away before sunset, although it isn't uncommon to see them standing about until the pubs close at midnight.

Bargaining is the traditional method for selling both cattle and sheep, but the emotional pitch of the bargaining sessions varies considerably. Bargaining for cattle is a much longer procedure that can take the better part of an hour. When a buyer approaches a cattle owner, he discusses general topics for a while before venturing to ask a price. The seller often refuses even to name his price and must be persuaded by a third party to do so. When a lower offer is made, the seller appears to be deeply offended by the suggestion that his animals might be worth so little. The intermediary has to soothe the seller's apparently hurt feelings before the bargaining can proceed. A new offer is then made, and this, too, the seller rejects.

So it goes, the seller displaying less vehemence and more uncertainty each time he refuses. Eventually, onlookers and an intermediary may persuade him to part with his animals, but the performance is always carried out with a good show of reluctance on the seller's part. Cattle are never criticized nor are comparative prices mentioned.

Buying sheep is quite different; it involves fewer offers and counter-offers and is carried out with an assumed air of indifference. A buyer asks the selling price, and the seller responds readily with some outrageous demand. The buyer prods a few of the sheep and observes that several of them may not make it through the winter. He then suggests a price that is much too low; the seller will ignore this commentary and the ridiculous price, even to the extent of pretending

Since fields are scattered outside the village, farmers herding their animals often take shortcuts through town.

Paul Slaughter

to be deeply engrossed in conversation with a bystander.

At this point an intermediary appears and the buyer will make another offer, after observing that Sean down the street is selling better sheep for 10 shillings a head less. The intermediary may have to interrupt the seller's conversation to point out that another offer has been made; again the seller will appear to be uninterested, but he will pause in the conversation long enough to suggest another price. Here the intermediary will suggest that the difference be split and both parties will consider the offer. If one or the other disagrees, the matter is dropped and there is no sale.

Performances in both these transactions are quite stereotyped and are carried out regardless of the amount of money involved; a bullock for $75 commands the entire performance, while sheep at $150 still receive the seemingly careless treatment described. Of course, the cattle owner is not truly offended nor is the sheep seller indifferent. These charades are games whose rules everyone knows. Styles differ, of course, as does aptitude for the performance. Both kinds of sale are concluded with a ritual handshake.

Payment for cattle is then made in the pub and all the onlookers join the principals for free drinks. Even the teetotaler must participate in this ceremony, although he need not drink himself. For sheep, payment in the pub is optional; sheep can be paid for in the street if the seller likes, but in a cattle sale this would be a serious breach of etiquette.

Violations of any part of the rituals can and do occur, although villagers feel some parts to be more important than others. Members of the younger generation may refuse to participate in the special handshake on the grounds that it is painful and unnecessary, but they will firmly agree that it is impossible to sell animals without the help of an intermediary.

The greater value of cattle is also apparent in legal distinctions. If a motorist hits a cow on the road, the motorist is always responsible for damages, although the law says that an owner must exercise care with his animals and the question of the cow's negligence may be hotly debated. Sheep, on the other hand, are responsible for their own welfare, and if one is struck, it is the owner's problem, not the motorist's.

To give an example of how the authorities will protect the rights of cattle, the county once charged a man with cruelty to animals because he had allowed the cows in his care to roam freely in winter. When the neighbors complained, he confined the herd to a field without adequate provisions for feed. (Cattle are normally kept in barns through the winter and fed on hay and grain supplements.) Several of the animals died and went unburied; a county official found the rest in an emaciated state, some so debilitated they had to be done away with.

The punishment for this offense was quite severe—a heavy fine and a suspended prison sentence. The judge expressed indignation at the man's conduct, noting with relief that such things seldom happened in the county and that such a case had never come before him.

It struck no one as odd that what was defined as cruel and unusual treatment for cattle is exactly that accorded to sheep every winter. Owners leave them to fend for themselves, turning them out to pastures they know to be insufficient. There is no thought of supplemental feeding, and in a severe winter, the mortality rate may be as high as 50 percent.

Another instance of the differentiation between cattle and sheep is found in animal health practices, specifically in willingness to consult a veterinarian. When I asked under what circumstances a farmer would call the vet, cattle farmers told me that even the least doubtful conditions would occasion a call, while sheep owners almost never consult a vet. The reasons for this were as numerous as the respondents: they weren't sure what the animals might have died of or they tried treating them with home remedies or, commonly, whatever the precipitating cause, the real cause was starvation and the vet wouldn't be any help for that.

Distinctions between cattle and sheep extend to their owners as well. Cattle farmers are said to be more intelligent, reasonable, and modern; more interested in community problems and affairs; more apt to be a good example to the rest of the people. Villagers characterize sheep farmers as lazy, backward, unwilling to contribute to the welfare of the community, and uninterested in anything except government handouts. True, sheepmen, even the wealthy farmers who have large herds, do not participate in local politics. Members of the local committees and those who hold positions of authority on special occasions are primarily cattle farmers, although some of these men may keep sheep as well.

Since there are no local elective offices, being a committee member or an official in charge of special events carries a good deal of authority and recognition. Recruitment for either of these offices is based on two traditional criteria: wealth and education. Wealth, which generally coincides with inherited position, usually means extensive cattle holdings. As for education, holders of certain posts, such as the village priest or the headmaster of the local school, automatically assume leadership.

Beyond this, some people who are neither wealthy nor well educated do participate, especially shopkeepers whose interests are affected by such things as local development committees or the annual agricultural show. The main point is that while there are factors that can influence political participation (a shopkeeper who lacks the benefit of inherited social position may still become a local leader), even wealthy sheep farmers do not participate in the authority structure.


Paul Slaughter

The reputation of sheep farmers as noncontributors to the economy is also interesting, especially when contrasted to the feelings about cattlemen. Since the sheepmen occupy some of the poorest lands in the area, they are almost invariably eligible for unemployment compensation. But the unemployment rolls are by no means composed simply of sheep farmers. Furthermore, the reputation stems not so much from these realities as from social behavior. Villagers expect cattle farmers to buy drinks in the pub, and those who do not are apt to be thoroughly damned. For sheep farmers, however, participation is optional, but since the definitions of a man's social and economic worth depend on his display of generosity and his willingness to spend his earnings where they are earned, such farmers must work harder to avoid the reputation of stinginess.

Local residents consider raising cattle a worthwhile occupation, and when asked to explain their reluctance to increase sheep numbers, explain that cattle raising is less arduous. In fact, the care of sheep, which are put out to pasture during the winter months from November to March, involves less work. Sheep are handled only when they are shorn, inoculated, and dipped. Otherwise, they are left to fend for themselves, and no special care is taken to feed or protect them.

This contrasts with the daily care farmers provide for cattle. Cattle graze in fenced pastures or under the eye of a herdboy, and farmers who do not have fenced pastures generally keep their cattle in at night (there are no predators to harm them, but the terrain is treacherous). Owners must provide cattle with hay and grain supplements, usually purchased, through the winter. The hay requires a summer's labor in "saving the hay," a picturesque phrase that often reflects harvesttime realities. Cattle keeping is a labor-intensive occupation, and the low mortality rates indicate the attention given to these animals.

Although less arduous, sheep farming is a lonely occupation, requiring long walks to look after the animals—perhaps rescue one in trouble or aid in lambing. Most of the work involved in caring for sheep can be carried out by one or at most two men. Sheep herding seldom demands group cooperation, and in the past, before dipping became mandatory, it must have demanded even less. Group effort is usual only at shearing and dipping time.

Cattle farming, however, demands group efforts at many times of the year. Saving the hay is a laborious task and all the members of a local group participate. The appropriate harvesttime is decided by this group, not by the individual farmers. Then the group participates in the various steps involved, culminating in the thatching of the haystack at each man's home. This occasions a week or more of visiting, eating, and other socializing. Calving is also an important occasion and one's neighbors are often called upon for aid or advice.

The entire process of giving care and attention to cattle insures that a farmer is dependent on his neighbors, that he must cooperate with them and render aid and assistance when asked. Cattle act as an integrating force within the community. Sheep herding is exactly the opposite: a man needs little help with his sheep and can be as individualistic as he chooses.

Cattle are the prestige product of the area: sheep have little value for prestige purposes. This value system has strong ecological underpinnings, for the keeping of the two kinds of animals has markedly different effects: cattle, unlike sheep, recycle the energy they utilize. From a nutritional standpoint, cattle provide most of the dietary staples. Directly, they produce milk and milk by-products, the protein sources; indirectly, their manure fertilizes the fields for potatoes, oats, and wheat, the carbohydrate components. Milk and potatoes have been the basis of the Irish diet since the seventeenth century; such luxury items as fish, bacon, and even flour were uncommon until well after the turn of the twentieth century.

In effect, cattle are the arbiters between man and his harsh environment. Socially, cattle provide a basis for cooperation; ecologically, they use the grass that grows abundantly in this wet climate and convert into food a resource otherwise inaccessible to man.

In contrast, sheep are the scavengers of the system, providing nothing except cash in return for the energy they take from the land. Even their wool has little value (the wool for the famous Donegal tweeds comes from England and Australia, not from the Donegal black-faced sheep). Most people consider investment in sheep a foolhardy business. If nothing is ventured, it may be the case that nothing is gained, but more importantly, nothing is lost. In a good year, sheep will find enough to eat, the lambs will survive, and a farmer can make a small profit on the sheep he handles so carelessly; in a bad year, he may make nothing, but if he has invested nothing, there has been no loss.

Ecologically, then, the system tends toward its own equilibrium, but investment in sheep would throw the balancing mechanisms out of kilter and farmers might be inclined to try to keep the sheep alive by taking some reserves from the cattle. If cattle and sheep were valued equally and scarce resources were allocated to the sheep, then the cattle population would suffer and with it, the human population. □

At one time, traditional brindled cows were the only ones raised in Donegal, but since the advent of an artificial insemination service, farmers can select a greater variety of breeds.

Celestial Events

by Thomas D. Nicholson

Sun and Moon This is the month when the sun arrives at that point called the vernal equinox. The name obviously implies that at the vernal equinox, spring begins and days and nights are equal. However, it's the beginning of spring only in the Northern Hemisphere; south of the equator it's autumn.

Full moon occurs almost exactly at mid-month in March—on the 15th—and in April on the 14th. So expect the evening crescent to show up in the middle of the first week, first-quarter moon at the end of the week (the 8th in March, the 7th in April), last-quarter at the three-week mark (the 22nd in March, the 21st in April), and the change of the moon (new) at month's end (March 30 and April 29, respectively).

Stars and Planets Mars and Saturn are well placed in the early evening: Mars well up in the south at dusk, Saturn to its left. But Mars is not nearly as bright as it was last December. It loses half its brightness again this month. Saturn is far brighter and easy to identify below the twin stars, Pollux and Castor, in Gemini.

Occultation by Mars On April 7, at about 8:00 P.M., EST, Mars, moving eastward in its orbit, will cover the third-magnitude star Epsilon Geminorum for about five minutes. Such an event—a planetary occultation—is not particularly rare but seldom involves a star as bright as Epsilon, which is about one-fourth as bright as Mars. The event should be easy to follow by anyone using a simple optical aid.

The occultation will occur after dark along the East coast and in twilight or daylight farther west. The star will be just to the left (east) of Mars. You should begin looking no later than 7:30, although times will vary slightly from one viewing site to another. Mars, moving slowly left, should cover the star a few minutes before 8:00 P.M., then uncover it a few minutes later and move on to the left.

What you will really be seeing during the occultation is the shadow of Mars—cast by the light of Epsilon Geminorum—as it moves past earth.

March 16: The perigee moon occurs 13 hours after it was full. Perigee will enhance the normally high spring tides we can expect today.

March 17: The moon is very near Spica, in Virgo, tonight. It actually covers the star over parts of Europe, Asia, and Africa.

March 20: The sun arrives at the vernal equinox at 6:50 A.M., EST, and spring begins in the Northern Hemisphere.

March 27: Saturn becomes stationary, ending its retrograde (westerly) movement and beginning its normal movement to the east (left) through the stars of Gemini.

March 31: The moon is at apogee, farthest from earth.

April 6: Mars is above the first-quarter moon at dusk tonight, and the brighter Saturn is to Mars's left. The moon will move slowly away from Mars and closer to Saturn. All three will set at or before midnight.

April 7–8: The moon, while waxing in size, is between Mars and Saturn on the evening of the 7th, still moving closer to Saturn. By the evening of the 8th, it will have moved to Saturn's east (left).

April 14: The moon is at perigee today, five hours before it is full. Once again the effect of perigee will be to strengthen the spring tides today and tonight. The star near the moon is Spica, in Virgo, covered by the moon in South America.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 10:25 P.M. on March 15; 9:20 P.M. on March 31; and 8:20 P.M. on April 15; but it can be used for an hour before and after those times.

Helmut Wimmer

Deep Divers of the Antarctic

by Gerald L. Kooyman

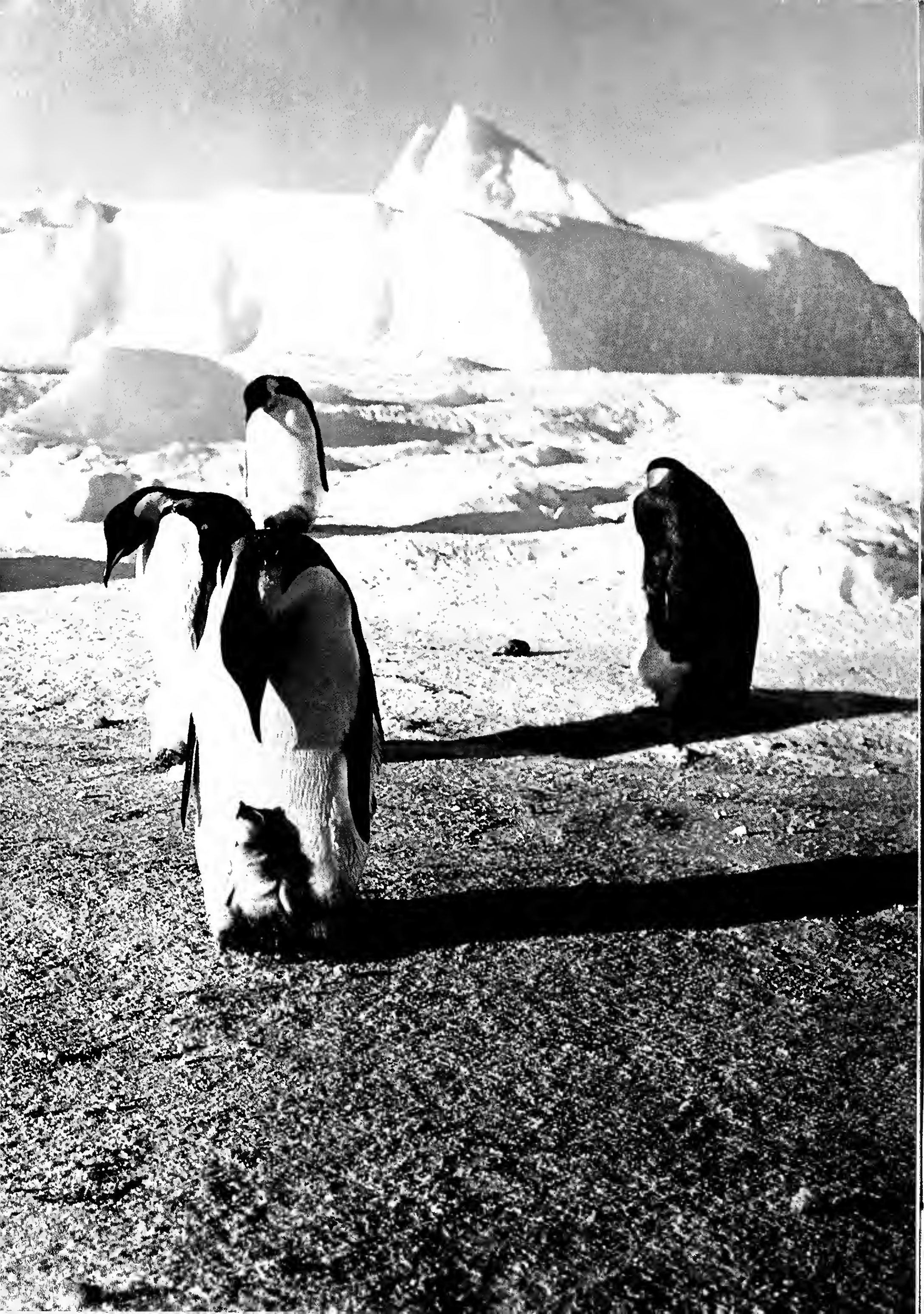
Emperor penguins, flightless seabirds that move clumsily on land, are excellent swimmers and seem to "fly" when under the water.

Emperor penguins and Weddell seals need special adaptations to survive in one of the most severe habitats on earth

Two large warm-blooded animals—the emperor penguin and the Weddell seal—have overcome the forbidding environment of Antarctica to make it their year-round home. Unlike the host of other birds and mammals that come to the continent only in the summer to breed and to feed on its abundant marine life and then depart for either the pack ice or lower latitudes, these animals stay throughout the severe winter.

The emperor penguin has been known as a species, *Aptenodytes forsteri,* only since 1844. Yet, it is one of the largest of all birds and is *the* largest extant aquatic bird. Males can be up to four feet tall and some weigh more than ninety pounds, although the average weight of the species is between fifty and sixty pounds. The emperor's nearest relative is the king penguin, *Aptenodytes patagonica,* which lives on and around the subantarctic islands, particularly on South Georgia Island. Both species are similarly striking in their markings, with black backs and white to yellow breasts. The long and slender bill, which the emperor frequently uses along with its flippers for helping to raise itself out of the water and from a prone to an upright position, is delicately marked with blue and pink borders on a black base. The feathers, except for those on the wings and tail, are uniformly one to one and a half inches in length. They are narrow, with a downy filament at

Gerald L. Kooyman



the base, and give the superficial appearance of fur.

Emperor penguins feed mainly on fish and squid rather than on the surface-dwelling krill favored by many other penguin species. As a result, emperors must frequently dive under the ice and into deep water in their search for food. I am fortunate in having had the opportunity of making diving studies of these birds. These were probably the first such studies of any penguin, previous investigations having dealt primarily with penguin reproduction on land.

The procedure used was the same as that I had already employed in studying Weddell seals. An ice hole was cut well away from any other cracks or holes to which the diving birds might go. This forced them to return to our hole. A heated laboratory hut of sufficient size to provide researchers easy access to the deep sea below was placed over the hole. And an observation tower was lowered through the ice thirty feet away from the hut. The tower enabled us to sit about ten feet below the ice and observe much of the birds' diving activity. Although the six-foot-thick ice made it rather dark down there, the ice, in combination with the long winter night, suppresses plankton growth, and the result is perhaps the clearest surface water anywhere in the world. In some localities objects can be discerned underwater up to 600 feet away and meaningful light and dark areas can be distinguished at a distance of almost 1,000 feet. Under these circumstances, we released penguins, some wearing instrument packs, into the ice hole.

Because of the color pattern of the penguins, we lost sight of them at about 200 feet. Nevertheless, we did learn several interesting things from these experiments. By training some birds to swim between two holes spaced a known distance apart, we measured a maximum swimming speed of 5.2 mph, much slower than the illusion penguins give when maneuvering. We also discovered their acrobatic proclivities. I saw one bird virtually pinwheel on its wings and reverse swimming direction. The turn was so quick I could hardly follow it. The fastest ascent rate we measured was 400 feet per minute, an impressive figure considering the rapid pressure equilibration necessary if the ascent is made from a great depth. The longest dive in nearly 250 observations lasted eighteen minutes. This is considerably longer than the diving durations recorded for any other bird and longer than the dives of many marine mammals. The deepest dive measured was less than 130 feet, a surprisingly conservative figure probably influenced by our research methods and the fact that the birds were diving singly.

When released in the ice hole, a bird would spend all of its time seeking other exits or trying to make one by using its stout beak as a battering ram. Therefore, I organized a trip to Cape Crozier to measure the diving depths of birds at the ice edge, where I was sure they were feeding and their dives would, accordingly, be different. I knew from previous trips to the Cape that birds departing from the rookery wait in groups at the ice edge, dive together, and after several dives, return. Taking advantage of this behavior, we placed depth recorders on twenty-five birds. This device consists of a capillary tube in which the interior is dusted with a water-soluble dye. Any compression is indicated by a ring in the capillary. The instrument, devised in the mid-1800s by Lord Kelvin, the British mathematician and physicist, was a major innovation in that it permitted ships to make soundings while under way, rather than having to stop and drop a weighted line.

While we waited for the birds to return to their rookery, we watched them dive in groups as large as twenty-five to fifty. Their dives were literally made under our feet. The sea was glassy and we could see the penguins swimming vigorously as they disappeared from sight below us. They surfaced several minutes later, still in groups, breathing deeply in open-beaked gasps. On recovering our recorders, we were rewarded with a maximum depth measurement of 885 feet, probably the deepest dive.

The Breeding Cycle of Emperor Penguins

Birds begin arriving at most of the rookeries in late March—the end of the antarctic fall. (They arrive from thirty to forty-five days later at the more southerly rookeries such as at Cape Crozier.) Courtship, involving visual and vocal displays, begins immediately and from late May through the middle of June—wintertime—the birds lay their eggs. Females fast during the courtship and laying period and lose about 20 percent of their body weight. The female emperor lays only one egg and then departs for the sea to feed, leaving her male partner in charge of incubation.

For about two months, the males incubate the eggs on the tops of their feet under a flap of highly vascularized skin called an incubation patch, or pouch. This pouch promotes heat transfer and keeps the egg at 90° to 100° F despite winter temperatures known to dip as low as −50° F. Males take no food during incubation, living on stored fat reserves, and lose up to 50 percent of their body weight during that period.

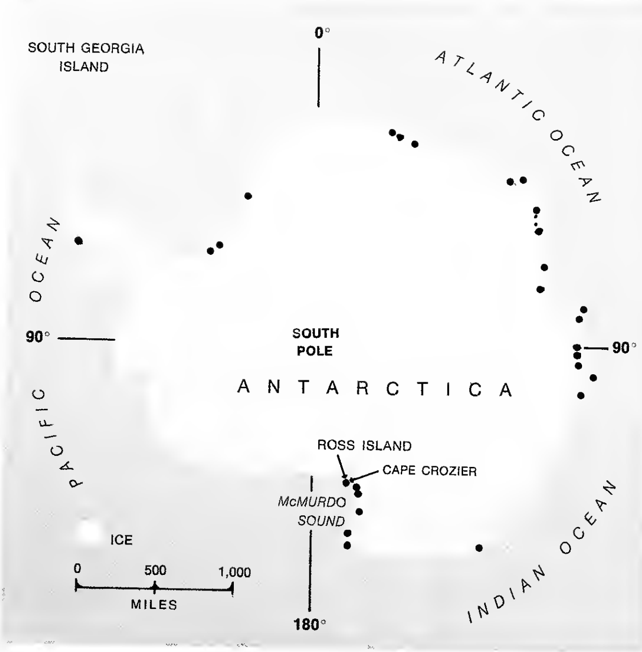
Females return to the rookery about mid-August, the time of hatching, to relieve the males. At hatching, the penguin chicks weigh just under one pound and are covered with a coat of down. For approximately the next six months—from the antarctic late winter through summer—until the time the chicks fledge, males and females take turns caring for and feeding the young.

By the time fledging ends, sometime between December and February, the young have become independent and can find their own food at sea. The independence of the young penguins leaves the parents free to go to sea themselves until March when they return to the rookery to breed again.

At Cape Crozier, a chick about one month old is sheltered by one parent while the other is away searching for food in the sea.

Gerald L. Kooyman

Clifton Line



Twenty-nine emperor penguin breeding sites have been located by aerial survey along the Antarctic coast. They are shown here by dots. Although most of them are on sea ice or barrier ice, a few are on beaches.

ever recorded for a bird. (By comparison, according to the *Guinness Book of World Records,* the deepest dive made by a human being wearing scuba equipment is 437 feet.)

Impressive as these penguin statistics are, they pale alongside those of the Weddell seal, the other year-round resident of Antarctica, named for James Weddell, a British explorer who first collected specimens during his voyage to the Antarctic between the years 1822 to 1824. The species is large for seals; adults can exceed ten feet in body length and weigh more than 1,000 pounds. The chest and stomach are a mottled white and black or dark brown and the back is a uniform black or brown.

Weddells usually inhabit areas south of the Antarctic Convergence (the ocean boundary that separates the waters surrounding Antarctica into antarctic and subantarctic regions), although strays have been found as far north as South America, New Zealand, and Australia. The most northerly breeding ground is South Georgia Island, where a small number pup each year. Around Ross Island in McMurdo Sound, where my studies were made, several hundred pups are born from late September to early November—the antarctic spring. At birth the pups weigh about 55 pounds and are approximately 45 inches long. The mother provides them with one of the richest of milks, sometimes containing over 70 percent by weight of fat and protein. On

A Weddell seal slithers into the freezing water of McMurdo Sound. These animals come out of the water primarily to sleep on the ice.

Mannenng & Associates

this diet the pups gain weight rapidly, and after six to seven weeks, when they are weaned, they have gained as much as 200 pounds. The mother eats very little while nursing and endures a considerable weight loss of up to 300 pounds. She ends nursing by abruptly leaving the pup one day and not returning. After a few days of raucous bleating—and perhaps even attempting to get milk from another mother—the pup begins to move farther and farther from its birthplace. At this time of year, December—which is antarctic summer—the fast ice (solid sheets of ice fastened to the shore) is breaking up, there is much open water, sea food is in abundance, the weather is relatively mild, and circumstances are ideal for these young diving amateurs. Only an occasional killer whale pack is likely to disrupt their tranquility.

As winter sets in, although most adults remain, the young Weddell seals and some adults leave the southern regions of Ross Island for parts unknown. Those that stay continue to dive and feed under the newly forming ice that rapidly thickens to several feet, reaming breathing holes through the thinner areas as required. A secure ice platform containing spaced breathing holes made by the seals offers almost unlimited research opportunities, and for several years, beginning in the late antarctic winter and early spring, I conducted studies of Weddell seals in order to learn what I could about their diving behavior and physiology.

Following a procedure later copied in investigating the emperor penguin, a seal was released from an isolated hole. Because of the animal's size, the process was a little more complex with seals than with emperor penguins. A seal was towed to the hut in a large enclosed sled. The sled was backed up against the hut door and then opened. The seal usually crawled directly into the hut, entered the ice hole right away, and began diving. But occasionally a seal did not enter the water for several hours and then we were obliged to share our hut with the animal for the evening or the night—which reminded us of the joke about where does a 500-pound gorilla sleep.

A seal's first dives are usually short and shallow as the animal familiarizes itself with the under-ice surroundings of its new location. Soon, either deep-feeding dives or exploratory dives are begun. I was worried initially that a seal might become confused and drown under the ice. But it quickly became apparent that the animals have superior diving abilities with regard to depth and duration and can find their way around underwater. While feeding, they would commonly dive to depths of 600 to 1,200 feet. These dives lasted from eight to fifteen minutes. The deepest dive measured was to the bottom of McMurdo Sound at a depth of 1,970 feet. This is one of the deepest dives ever recorded for a marine mammal.

Especially interesting were the seals' exploratory dives. Unlike the deep dives, which were made directly below our hut, in exploratory dives the seals swam a considerable distance away from the hut and the vital breathing hole and never descended deeper than 600 feet. Presumably, those exertions were attempts to find other seals or other breathing holes. Because of recording equipment the seals occasionally carried, we know something of the nature of these dives. The longest exploratory dive recorded lasted seventy minutes. This is one of the longest natural dives recorded for any marine mammal, although sperm and bottlenose whales have remained submerged for even longer periods after being harpooned. Long-lasting dives were rare, but dives of twenty to forty minutes duration were common. All of these forays took place at depths of less than 600 feet as the seals swam possibly up to six miles from one breathing hole to another.

My observations of seals convinced me that there is almost nowhere in the Sound that they cannot reach. Any small break in the ice they can breathe through is likely to be

Russ Kinne, Photo Researchers

found. Even in the most isolated areas, marine biologists making ice holes or scuba dives are likely to find a seal approaching from below.

The diving abilities of the emperor penguin and Weddell seal raise a variety of questions about how these animals function. For instance, what anatomical and physiological features enable the animals to withstand the enormous pressures they are exposed to when they dive deeply? And how are they able to hold their breath for so long? The most extensively studied aspect of the physiology of diving birds and mammals is the modifications that make extended breathholds possible. Since breath-holding responses in both birds and mammals are similar, one explanation applies equally to both groups.

We know of two fundamental ways that enhance the capacity of animals to hold their breath. One is the increase of body oxygen stores; the other is the parsimonious utilization of those oxygen reserves. For example, the blood hemoglobin concentration of Weddell seals—and consequently the oxygen-carrying capacity of their blood—is 1.7 times greater than in humans. Similarly, the O_2 carrying capacity of the emperor penguin is 1.6 times greater than that of the domestic chicken. Furthermore, the total blood volume of the Weddell seal on a per weight basis is twice that of man. (But the blood volume of penguins on a per weight basis is no different from that of chickens.) The muscles of both penguins and seals contain a significantly higher concentration of myoglobin, an oxygen-binding molecule, than occurs in terrestrial birds and mammals. The net result is a larger total body oxygen store. However, the lungs of penguins and seals are not larger than those of terrestrial animals and contribute no more to the total oxygen store than the lungs of any other bird or mammal.

When penguins and seals dive their large body oxygen stores are husbanded. This is accomplished by a major change in their blood circulation. Flow to tissues capable of periodic anaerobic or lowered metabolism, such as muscles, kidneys, or the gastrointestinal system, is decreased while flow to tissues of high aerobic and metabolic needs, such as the brain, are maintained. These flow changes are reflected in a lowered heart rate and cardiac output, which may drop to 10 percent of the predive level. The result is a significantly lowered consumption of oxygen during the dive and thus an ability to extend the breathhold.

Heart rates were measured during portions of Weddell seal dives. The usual method of measuring heartbeat rates is to place a positive and a negative electrode on opposite sides of the chest and connect them with three- or four-foot lengths of wire to a recorder. The recorder monitors the electropotential change that occurs within the body each time the heart muscles contract. We followed this conventional method, except that our wires were 200 feet long and had breakaway connectors. When the seal reached the end of the line, the connectors parted and terminated the recording until the next dive, when they could be plugged in again. This method permitted us to measure heartbeat rates during the entirety of some shallow dives and the early parts of deep and exploratory dives.

The recordings indicated that the degree of heart slowing depended on the type of dive. During shallow resting dives just below the ice hole, the heart rate dropped from a surface average of fifty-five beats per minute to a rate of twenty-five to forty. If the dive was deep, the rate dropped lower, and it was lowest of all on exploratory dives, when it sank to fif-

To guard against predators, young emperor penguins stay in a group called a crèche, where they are tended by a few adults.

teen beats per minute. It seems quite logical that during the longest dives blood flow would be most restricted and oxygen stores be most slowly utilized. The heartbeat rate, however, is believed to be autonomic, or involuntary, yet the drop took place so quickly, it almost seemed to anticipate the dive. One can only wonder how that is achieved.

When Weddell seals and emperor penguins dive to great depths, those portions of the body that are most affected by mounting pressure are gas-filled spaces because their volume must change considerably as the animal descends. The largest gas-filled space in the body is the respiratory system, consisting of the trachea, or windpipe, and the lungs. The respiratory system of the Weddell seal, however, is structurally very different from that of the emperor penguin. And the seal's lungs are also somewhat different from those of terrestrial mammals. The airway system in the seal, which is the transport system of air to the gas-exchanging alveoli, or air cells of the lungs, is more extensively strengthened than in terrestrial mammals. The extra support consists of cartilage, muscle, and connective tissue. Experimental evidence indicates that the added reinforcement insures that when the animal descends, its lungs compress differentially. The alveoli, being more compliant—that is, capable of readily changing shape—than the airways, compress the most and the gas within them is forced into the airways. Since at great depth many or most alveoli are collapsed, there is very little gas exchange between alveoli and blood and the gas is sequestered in the non-exchanging airways. That this collapse will also occur at shallow depths is assured by the seal's behavior. As the seal dives it exhales one-half to two-thirds of its lung volume.

A stoppage of gas exchange at depth means that oxygen stored in the lungs is unavailable for consumption. However, it is a small amount of the total body O_2 store. More important is that nitrogen at high pressures is not taken up by the blood and accordingly does not expose the seal to decompression sickness—the bends—when the animal surfaces.

The penguin respiratory system is neither as well studied nor as well understood as that of the seal. It consists of several air sacs distributed throughout the body and connected to the lungs by conducting tubes. The air sacs have a far larger volume than the bird's lungs. When the penguin dives it inhales deeply and most of the gas is stored in the air sacs. The volume of these sacs relative to body weight is up to eight times greater than the lung volume in the seal. The oxygen volume in the penguin's air sacs represents a large proportion of the bird's total body O_2 store; the rest is in the blood and muscles.

Under experimental conditions, Adélie and gentoo penguins have been put through simulated dives at pressures equivalent to those at 230 feet. In these circumstances, gas exchange between air sacs, the lungs, and the bloodstream continued and the tissues were exposed to high nitrogen tensions. But the birds did not get the bends, perhaps because the exposure to high pressure was brief. These two species of penguin cannot hold their breath for more than five minutes, and under natural conditions they rarely dive for more than one or two minutes. Similar experiments have not been done on emperor penguins but it is likely that tests would yield analagous results since the respiratory systems of all three species appear to be similar. This makes the emperor penguin something of an enigma. It commonly remains submerged for five or ten minutes while diving to great depths, and it is not clear how the bird avoids getting the bends when it surfaces.

The final and most frequently asked question about aquatic polar animals is, How do they maintain their body temperatures in the frigid air and water? When the penguin chick hatches it is covered with a fluffy coat of down. When the seal pup is born it is covered with a long fur called lanugo. The insulation of the penguin's down is only about one-half that of the fur coat of the arctic fox and the seal's lanugo is only about one-third as effective. These deficiencies, however, are not too important since adult plumage replaces the chick's down within a few months of hatching and the pup acquires another type of insulator one or two weeks after birth.

The tips of the feathers of the adult emperor penguin overlap like tiles on a roof, forming a waterproof shell, and the downy portion at the base traps a layer of air next to the body, conserving its heat. This plumage enables the bird to tolerate air temperatures as low as 14°F without making any effort to keep warm. That is no match for some arctic mammals whose thermoneutral zone extends to at least −60°F, but the emperor penguin's plumage represents a compromise—it has to be effective in water as well as air, and the requirements for a water-repellent, streamlined coat are different from one functional in air only.

The heat conductivity of water is more than twenty times that of air. Measurements of the metabolism of Adélie penguins show that it increases to three times the resting rate after they enter water. Presumably, a similar increase is necessary for the emperor penguin because when it remains inactive after entering the sea, it soon begins to shiver. In contrast, the adult Weddell seal does not rely on its pelt for insulation, but rather on a thick layer of subcutaneous blubber that begins to develop immediately after birth. This type of insulation, which conducts heat at about the same rate as asbestos, is so effective that the seal can rest comfortably in 28°F seawater. When a severe storm occurs, rather than be blown by winds that can achieve hurricane force and pelted with ice and snow on the surface, Weddells take shelter in the water until the storm subsides.

Two questions I have not answered are, Why don't deep-diving penguins suffer from decompression sickness on surfacing? And how do emperor penguins and Weddell seals navigate under the ice? On future visits to Antarctica, I plan to look into these matters, as well as other aspects of diving behavior and physiology, in the continuing search to learn how these animals function in one of the most hostile environments on earth. □

Weddells, which are believed to see exceptionally well in dim light, spend most of their time in the water.

George Holton

The Predatory Baboons of Kekopey

by Robert S. O. Harding and Shirley C. Strum

These primates, rapidly learning to exploit a new food resource that resulted from an antelope population explosion, are causing speculation about early man's meat-eating habits

The olive baboons moved slowly across the African plain that lay deep in the shadow of the cliffs on whose ledges the troop would sleep in safety for the night. Suddenly, an adult male stopped in the foot-high grass and pounced. The sharp bleat that followed betrayed the presence of a newborn Thomson's gazelle, still too weak to outrun its captor.

The baboon held the infant to the ground and tore at its soft belly with his teeth. When the antelope stopped moving, the baboon commenced eating, but perhaps intimidated by the presence of other male baboons, which had approached and were staring at the scene, he picked up the carcass in his jaws and ran twenty yards away. The others pursued. Within an hour the male had consumed most of the flesh, but as he walked away from the remains another male quickly seized the last bits of flesh and skin.

Incidents of this sort have become quite common among the baboon troops that range freely through Kekopey, a cattle ranch near the village of Gilgil, 70 miles northwest of Nairobi, in the Central Rift Valley of Kenya. Although Kekopey comprises 45,000 acres, the grass that grows sparsely in the arid climate supports only 4,500 cattle. Large portions of the ranch are covered with lava rubble, and other evidence of the volcanic activity that characterizes much of the rift valley is scattered throughout the area—steam hisses from cracks in the earth, and extinct ash cones and craters dot the landscape.

The central part of the ranch, however, consists of open grassland broken by patches of an aromatic camphorous shrub that the Masai people call *leleshwa.* Additional grassland has been created over the years by ranch workers who cleared away some of this scrub. Water troughs for cattle are scattered over much of this open land, and many kinds of animals take advantage of the ready supply.

Impala and Thomson's gazelle are the dominant antelope species in this part of the ranch. In 1970, when we first began our study, their exact numbers were not known, but a survey on 18,000 acres of open grassland and scrub on the ranch resulted in a count of 800 impala and 1,600 Thomson's gazelle. Baboons also inhabit this part of the ranch; our 1970 census, which covered some of this area, showed seven troops ranging in size from 35 to 135 animals and living in overlapping home ranges.

Predators had been greatly reduced but not completely eliminated. To permit the raising of domestic stock, the lion population had been systematically destroyed by shooting. And in recent years, ranch owners live-trapped some of the ranch's leopards for removal to national parks in Kenya. Some cheetah remained but we sighted them only infrequently.

The ecosystem at Kekopey has thus undergone considerable modification over the years. Baboons, however, have for the most part escaped the human harassment that is their lot elsewhere in Africa, where they are trapped for medical experimentation or killed because of their fondness for human food crops. Despite the obvious alterations in the ecosystem, we decided to proceed with our research in this natural laboratory.

Although baboons subsist mostly on grasses, seeds, roots, and other plant matter, they were known to occasionally capture and kill small animals. Sheepherders in southern Africa, for instance, have long complained of baboon troops raiding their herds and taking young lambs. And a number of scientists had described baboon predatory behavior, but in no case had they reported a troop killing more than 20 animals annually.

As a result we were not surprised to learn that the baboons at Kekopey killed and ate small animals, but we did not anticipate the extent to which they engaged in this behavior. During the first year's research, we saw members of the one troop we were studying kill and eat 47 small animals—principally baby gazelles and some hares. This was a meat-eating rate higher than any then reported for a nonhuman primate group.

Baboons spend the greater part of each day feeding and moving from one foraging site to another with other members of their troop. Movements are usually unhurried, with individuals stopping from time to time to feed on the grasses and other vegetation that cover the valley floors. Our observations disclosed that it was during such leisurely progressions that many of the killings of small prey took place. Since both hares and young antelopes attempt to conceal themselves from predators by crouching in long grass or behind bushes, some of the baboons located and killed these animals by chance in the course of normal troop movement.

Yet, as we became more accustomed to the baboons' usual movement patterns, we discovered that the troop was moving deliberately through herds of grazing Thomson's gazelle. And several times, adult males left the troop to detour through nearby gazelle herds, scanning the ground on all sides as they went.

Timothy W. Ransom

Robert S. O. Harding

Timothy W. Ransom

Males also explored the heavy scrub that small dik-diks frequent.

Of the fifty baboons in the troop in 1970, four were adult males and nineteen were adult females. At first, killing was predominantly a male activity. The adult females killed only three animals—infant hares. We never saw juvenile baboons even try to catch an animal. Of the three females who killed the hares, only one succeeded in keeping any part of her prey; the other two were chased and threatened by adult males until they dropped their catch. Capturing prey was not only largely a male activity, it was a solitary one as well. Although one male baboon once successfully took up the chase of a young gazelle driven near him by another male, the baboons did not seem to cooperate in running down prey nor did a male baboon voluntarily share his catch with another troop member.

In 1970 and 1971, two-thirds of all the animals killed were newborn antelope of various species, with Thomson's gazelle the most frequent. About one-quarter of the animals consumed were Cape hare, and the balance included a button quail and several other animals that we could not identify from the scraps the baboons left. We never saw troop members eating carrion, although they had several chances to do so, nor did they try to catch every animal of the appropriate size.

Their sleeping cliffs, for instance, abounded with rock hyrax, and although baboons eat these small furry creatures elsewhere in Africa, we never saw the study troop attempt to catch them. And although an adjacent troop often caught helmeted guinea fowl, the troop we were studying ignored flocks of these birds as they walked cackling through the baboons' midst.

By late 1972, the troop had grown to sixty baboons—the result of births and immigration of adult males from nearby troops—and the animals' meat-eating tendencies had increased. In 1,200 hours of observation between 1972 and 1974, we saw them capture 100 small animals, roughly twice as many as they killed during a similar number of hours in 1970–71.

Not only were the baboons consuming more meat; their behavior toward acquiring meat had changed as well. Adult females, which had shown little interest in meat eating during the first years of our study, began to capture prey in significant numbers—hares for the most part, but some infant antelopes as well. All females were now present at some of the kills but two, in particular, were present at more kills than several of the adult males, and always waited, patiently but persistently, at the site for the male to finish eating. While some watching males might give up and leave before the carcass was abandoned, these females remained, seemingly undaunted in their determination, and in the end, had their turn at the meat.

It did not take long before the females also became bolder; rather than drop an animal when a large adult male approached, a female might try to outrun or outmaneuver him and the attempt was often successful. During the period from 1972 to 1974, adult females caught 14 percent of all prey; we also noticed that immature

Timothy W Ransom

When her young is attacked by baboons, an antelope often will charge to within about five feet of the predators (far left). However, she seems to lose interest after the infant stops bleating. Baboons most often begin eating by tearing open the underbelly of the prey with their incisors, rather than with their sharper canines. They usually consume the meat on the head and legs last.


mothy W Ransom

This baboon mother was one of the first females observed to eat meat. And her infant was among the first to learn the new behavior.

baboons were becoming involved in meat eating. The offspring of the two females that seemed particularly interested in meat frequently had the opportunity to investigate prey, and predictably, they were the first immature baboons to eat meat. At first their presence in the vicinity of kills simply reflected their mothers' interest. But as they grew older and became more independent, their interest continued whether or not their mothers were present at a particular episode.

It was not only maternal bonds that helped meat-eating behavior to spread among the younger baboons; long-term male bonds with infants and juveniles also created opportunities for meat eating among the young baboons even when their mothers had no special interest in meat. Many young baboons thus began their meat-eating behavior as a result of their special, close relationship with a male.

Older juveniles often began eating meat by chance—stumbling across a meat-eating episode while chasing one another in play. Such incidents seemed to make little impression on the young baboons, unless one chanced to get a scrap or two of meat. Behavior changed markedly in such a case; the young baboon would begin to join the hangers-on at kills until, through patience and persistence, it too got some meat. Juveniles then began to seek out and capture prey on their own, to the point that in the period from 1972 to 1974, they caught 16 percent of the prey.

Over the years the tactics used by adult male baboons to obtain meat changed dramatically. They began to supplement fortuitous captures and occasional detours through grasslands rich in prey with more concerted and systematic efforts. Upon sighting a herd of gazelles as much as a quarter of a mile away, one or more males often left the troop and approached the herd. By January 1974, this was an almost daily event. At first each male acted independently, but adult males always remain constantly aware of each other's location and actions; as a result, when one male made a kill or seemed about to do so, the others often abandoned their own efforts and converged on the successful hunter.

In one such incident, three males noticed another male chasing a gazelle and ran toward him. To get to the scene of the chase, they had to ascend a small hill that concealed their approach from both predator and prey. Just as he was about to abandon the chase, the baboon in pursuit of the gazelle suddenly found the three other males blocking the prey's escape route. The closest male then took up the effort, and when he appeared to flag, another continued it. For a moment the gazelle appeared to be outrunning its pursuers, but it changed direction in response to a similar movement from the baboon chasing it, and in so doing, ran into the third of the newly arrived males. The gazelle almost escaped when the pursuing baboon momentarily hesitated, but a quick bite to the underbelly put an end to the chase.

From that point on, the male baboons gradually adopted this relay system as a regular stratagem, chasing their prey toward a nearby male instead of out on the open plain. Such joint ventures appeared to be more successful than those carried out by lone males.

Adult male baboons also began to scatter antelope herds more frequently in an apparent attempt to find young animals of suitable size. This tactic often revealed a young antelope breaking from cover in the grass to run after its mother. The baboons might then spend as much as two hours covering large amounts of ground in attempts to close in on the antelope mother and her infant. As this tactic became more successful, deliberate searching for other prey in different habitat—such as dik-dik in brushy areas—became less frequent.

The persistence of the male baboons' efforts was impressive. On several occasions the troop moved through one particular area for a number of consecutive days, and each time males unsuccessfully pursued the same young gazelle. Each venture lasted up to two hours and took the baboons as much as two miles from the rest of the troop, out of sight and, apparently, out of contact. Once, after hunting the same herd for three days, the males finally captured and consumed a young antelope.

In the beginning of 1973 the male baboons could not seem to discriminate between all-male herds and mixed or all-female herds of Thomson's gazelle. Since only those including females contained potential prey animals, the baboons at first wasted considerable time and energy in scattering male herds. Later, however, the baboons were able to assess the herds, ignoring all-male ones and pursuing only female groupings within a mixed herd.

For their part, the Thomson's gazelle began to show vigilance toward baboons, especially those herds that had been hunted several times in a row. Once a baboon of any size appeared, the gazelles became alert and moved off, the adult females herding their infants away from the baboons. This vigilance, in turn, created new difficulties for the baboons and may have offset, at least partially, the advantage they had gained through their innovations in hunting behavior.

During the first year's observations, baboons did not share meat voluntarily; indeed, the adult males who did most of the killing at that time were highly intolerant of other baboons in their vicinity. As predatory behavior spread through the troop over the years, however, we observed the animals eating simultaneously from the same piece of meat or pile of scraps and even moving aside to make room for other baboons. We saw none of the gestures that chimpanzees use in begging for meat nor did we see food items other than meat ever shared, even between a mother and her infant. Such meat-sharing relationships appear to coincide with already existing long-term bonds, such as those between mothers and infants or individual males and females.

Initially, individuals closely guarded their kills and tried to escape the presence of other baboons. Now each kill attracts spectators, some of whom share in the meat eating.

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Over the past five years, the troop appears to have developed more efficient and sophisticated methods of capturing and consuming prey. We shall never know how the predatory behavior began for the baboons were already eating meat when we began to study the troop, but we can make some educated guesses about why predation has developed to such an extent. The most plausible has to do with the apparent antelope population explosion that resulted when the natural ecosystem of Kekopey was altered for raising cattle. Thomson's gazelle, predominantly grazing animals whose preferred habitat is open grassland, have benefited the most from these changes.

While we can only speculate about the origins of the baboons' predatory behavior at Kekopey, we know a great deal about the social dynamics underlying its spread through the troop. The behavior clearly proceeded along preexisting lines of social bonding—from mother to offspring, male to juvenile, and between male and female. We do not know whether the behavior was initiated by one or several individuals, but it seems to have become firmly established and is at this time independent of any one individual.

In a series of experiments involving the introduction of new foods to groups of macaques, Japanese anthropologists have documented the importance of individual behavior and social bonds in the diffusion of new behavior patterns involving different food items in a primate group. At Kekopey we witnessed a natural experiment in which, once again, individual behavior and social relationships played crucial roles in determining which animals acquired the new behavior.

There is no reason to think that we have seen the full development of the baboons' potential for predatory behavior, but of course there are limits to its expansion. Chief among these is probably the size of the prey animal, for nonhuman primates usually prey upon animals smaller than themselves; the anatomy typical of monkeys and apes allows for the easy capture and consumption of such prey. We would be greatly surprised if these baboons began to capture adult impala or even adult Thomson's gazelle.

Just as social factors facilitated the spread of predatory behavior within the troop, they may also set limits. Most troop members are physically capable of capturing prey and eating meat, but females and immature animals will probably not become involved in the hunting behavior that takes adult males far away from the troop for long periods. Adult males are relatively mobile, often transferring from troop to troop. Females and young baboons, however, would have to abandon old behavior patterns, which have important integrative functions within the troop, and acquire new ones if they were to take part in extended hunting forays. As evidence of this behavioral difference between adult males and other baboons, females and young approached only those kills that occurred near the troop. They usually

In the early years of predation by the troop, confrontations (mostly bluffing) between adult males over prey were common. Such incidents occur much less frequently now and adult males seem to be more tolerant of each other.

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ignored those that took place at a distance, unless the prey was carried close to the troop.

Anthropologists have traditionally believed that only humans among the primates kill and eat animals as a regular part of their diets. Some have even felt that the hunting, meat-eating adaptation has been so important in human evolution that we would be better advised to turn to social carnivores—such as lions—rather than nonhuman primates as models for early human populations. Documentation of hunting and meat eating by chimpanzees at the Gombe National Park in Tanzania and elsewhere in Africa, however, has forced a modification of this position. With predatory baboons now added to the equation, we can identify a primate potential for predation, one that our earliest hominid ancestors must have shared. The baboon and chimpanzee studies demonstrate how sophisticated and successful predation can be among primates without any of the unique attributes of the human hunting adaptation, such as the ability to manufacture tools.

There are many differences, of course, between the predatory behavior of human and nonhuman primates, for while the diet of the earliest hominids may have resembled that of today's baboons or chimpanzees, archeological evidence suggests that early man took part in organized hunting forays. The killing of large animals in large numbers is unique to humans among the primates, and it is tempting to speculate that the ability to manufacture tools and the development of sophisticated communication methods may have been the key to successful hunting of this nature.

As far as primates are concerned, however, there is no doubt that the capture, killing, or consumption of even a single large animal poses problems that are of a wholly different order from those encountered in the hunting of small animals. By comparing human and nonhuman primate hunting patterns, we can learn much both about the behaviors and behavioral potentials we share and those that are unique.

Predatory behavior in primates probably did not have a single origin but may have developed at many different places and at many different times, possibly even under widely varying environmental conditions. This notion is important in considering human evolution for it suggests that basic human adaptations may also have had multiple origins. Considering the speed with which the baboons elaborated their predatory behavior, it is also possible that after an initial adaptive shift to a new behavior in early human populations, further development of this behavior proceeded more rapidly than we think. The behavior of the baboons also shows that individual and social factors could well have had an important influence on the perpetuation of new behavioral adaptations.

The spread of predatory behavior among the Kekopey baboons prompts us to appreciate the complexity of adaptive shifts, both behavioral and anatomical, and adds to our growing realization that simple hypotheses tend to retard, rather than advance, an understanding of human evolution. The realization brings us back to the original insights of Darwin and Huxley, who theorized that all primates are linked along a single evolutionary continuum, one in which artificial barriers erected by humans to assure their own unique status have no rational grounds for existence. □

ART OF THE NORTHWEST COAST INDIAN

In the world today, there is a commonly held belief that thousands of years ago, as the world today counts time, Mongolian nomads crossed a land bridge to the Western Hemisphere and became the people now known as the American Indians.

The truth, of course, is that the Raven found our forefathers in a clamshell on the beach at Naikun. At his bidding, they entered a world peopled by birds, beasts, and creatures of great power and stature, and with them, gave rise to the powerful families and their way of life.

At least, that's a little bit of the truth.

Another small part of it is that, after the flood, the Great Halibut was stranded near the mouth of the Nimkish River where he shed his tail and fins and skin, and became the first man. Thunderbird then took off his wings and beak and feathers to become the second man, and helped Halibut build the first house in which mankind spent his infancy.

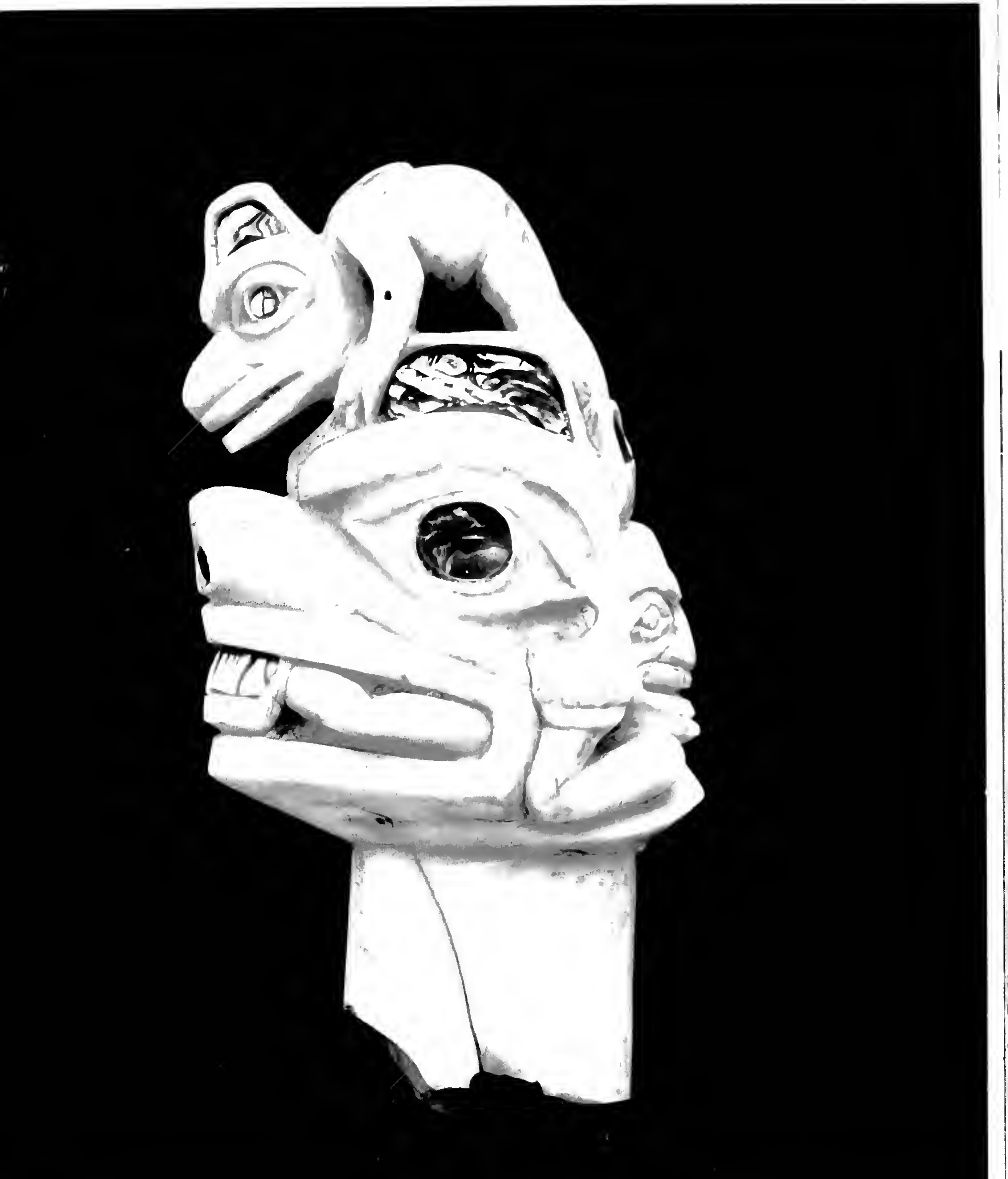
And the Swai-huay rose out of the Fraser. Needing a wife, he created a woman from the hemlock on the bank, and she, in time, gave birth to the children who became the parents of all men.

There is, it can be said, some scanty evidence to support the myth of the land bridge. But there is an enormous wealth of proof to confirm that the other truths are all valid.

William Reid

We invite you to see some of this proof—some of this wealth.

Dagger hilt of ivory, inlaid with abalone. Tlingit, early nineteenth century.



COLLECTORS AND COLLECTIONS

by Edmund Carpenter

The term *primitive art* legitimately applies, I think, to the art of the Pacific Northwest, not because that art was unsophisticated, but because its makers believed their ancestors lived in a primitive, mythological age, and they sought to reaffirm, perhaps reawaken, that reality by re-presenting it in art, drama, myth.

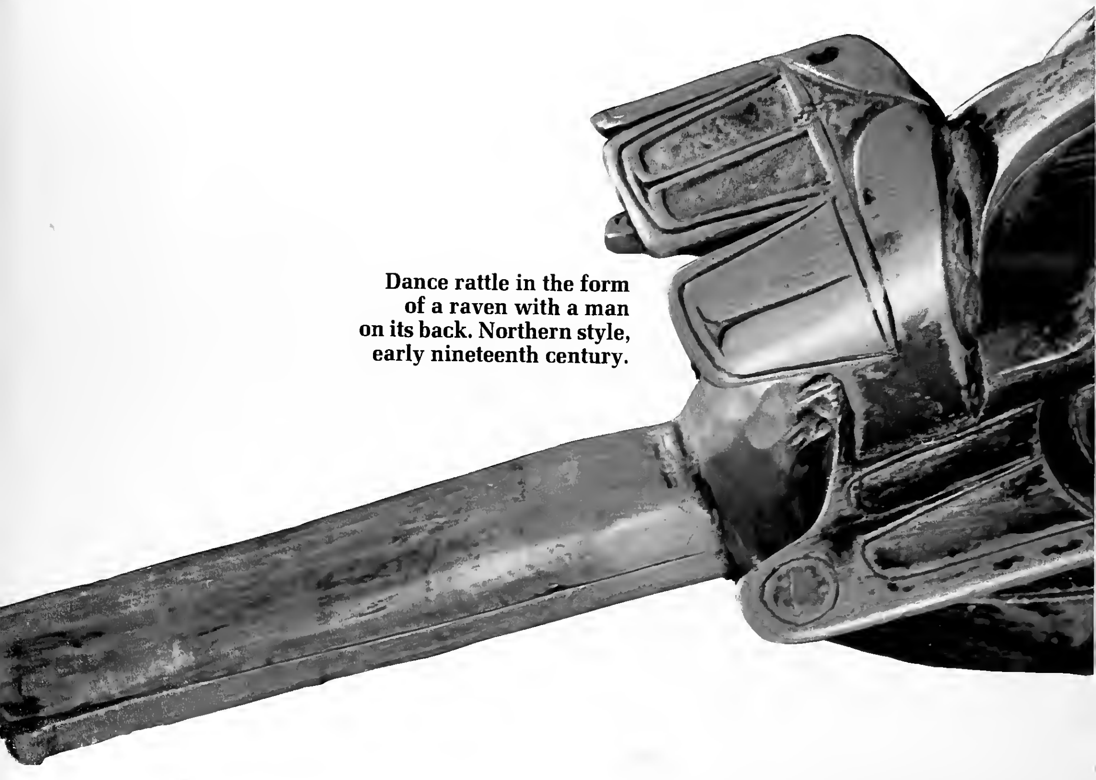
It was an age, they believed, of extraordinary events and noble deeds, when men lived as equals with animals and mythic beasts, and the play of Raven and Eagle, Frog and Beaver, Thunderbird and Whale established all that was to be.

When depicting that reality, Northwest Coast artists often showed two beings simultaneously occupying a single space by sharing various parts. Such visual puns did more than express complexity: they depicted transformation. Before one's eyes, Bear became Wolf, then Bear again. The image didn't change, of course. What changed was the observer's organization of its parts. But the effect was one of transformation.

This was wholly consistent with Northwest Coast thought. A Kwakiutl legend tells of the mythologic hero who appears first as a whale and later as a man disembarking from the whale, which is no longer himself but his canoe. When he meets the local chief and his daughter, whom he wishes to marry, he presents them with the whale, which has returned to its animal nature at the end of its third transmutation.

This single feature proved to be the one most difficult for early anthropologists to understand. When told a carving represented a bear and later told it represented a whale, they assumed there must be an error.

It remained for the Surrealists to explain this seeming contradiction. One day in the early 1940s, Max Ernst passed a shop on Third Avenue in New York displaying a few pieces of tribal art. The African pieces—so attractive to the Cubists—didn't interest him, but a Northwest Coast spoon did. The spoon was being sold as part of a collection of spoons from many lands. Ernst proposed instead,



Dance rattle in the form of a raven with a man on its back. Northern style, early nineteenth century.

Editor's Note on Pictures

In some cases precise identification of objects is not possible—labels have been lost, collectors' notes separated from artifacts, or pieces that were produced by one group were acquired in another's village. In these instances we have labeled the objects as being of northern style, which refers to Haida, Tlingit, and Tsimshian (southern would include all remaining groups—Kwakiutl, Bella Bella, Bella Coola, and others). All photographs: Hickey and Robertson; except page 62, Robert Mates and Susan Lazarus.

to buy a collection of Northwest Coast art, and the dealer agreed to assemble one.

Soon the whole group of Surrealists, who were then refugees in New York, and many of their friends, including Claude Lévi-Strauss, began to frequent "that shop on Third Avenue," buying in particular Northwest Coast, Eskimo, and Melanesian pieces. This emphasis was hardly coincidental. Northwest Coast, Eskimo, and Melanesian artists, perhaps more than any others, save the Surrealists themselves, emphasized visual puns, and it was visual puns the Surrealists collected.

During the last twenty-five years, I've examined most of these collections and talked to most of their owners. Their selections were uniformly good, yet only Lévi-Strauss, among them, was ethnologically knowledgeable. Apparently they approached these pieces directly, judging them in terms of inherent qualities. However unscholarly that approach, it resulted in superb collections.

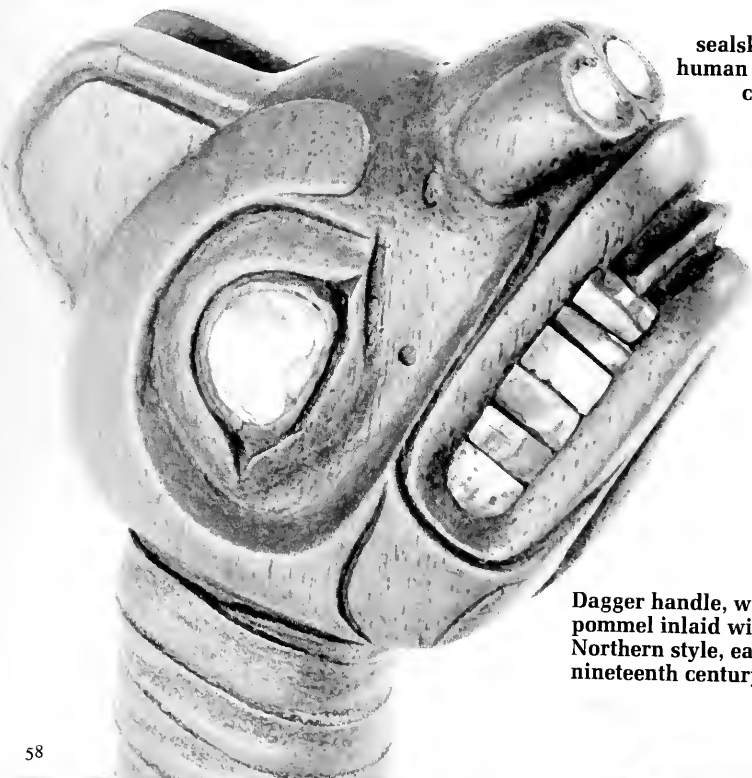
When I compare their selections with specimens I've seen decorating anthropologists' homes or illustrating their textbooks, I can't help asking, "Why did anthropological methods fail here?" Anthropologists, I think, were preoccupied with processes, not drama; concerned with relationship, not being. They were convinced value lay in function. They saw tribal art as a variant of material culture and they used it to answer questions about evolution and diffusion. Later they became interested in art's social or psychic "functions."

Anthropologists like to say that the study of tribal art begins with this question: What did this art mean to the people for whom it was originally intended? Yet it is precisely here their methods betray them, often leaving them in possession of—or in defense of—souvenirs. The Surrealists, by contrast, chose masterworks as judged by the tribes that produced them.

Several of them, including Max Ernst, then arranged an exhibit entitled "Northwest Coast Indian Painting." It was held in 1946 at a New York gallery. There they displayed pieces from their own collections, plus eighteen borrowed from The American Museum of Natural History.

The American Museum of Natural History offered a curious paradox. On public display was an incredible wealth of Northwest Coast art. Yet every piece was classified and labeled as a scientific specimen. Tribal carvings were housed with seashells and minerals as objects of natural history.

Portrait mask, with sealskin moustache and goatee, human hair. Tsimshian or Haida, ca. late eighteenth century.



Dagger handle, with wooden pommel inlaid with abalone. Northern style, early nineteenth century.

Sheep-horn bowl, designed and constructed following techniques developed in boat construction. Probably Tlingit, nineteenth century.

Frontlet worn as a centerpiece on a ceremonial headdress, inlaid with abalone. Haida, nineteenth century.

Art was displayed in the Metropolitan Museum. Far more than Central Park separated these collections. Part of the gap derived from the anthropologists' insistence that ethnological specimens had meaning solely in terms of the social matrices from which they came.

The very accessibility of this great collection reinforced that classification, preventing viewers from experiencing these objects artistically. By taking them off display in one part of New York and putting them on display in a gallery a mile away, the Surrealists declassified them as scientific specimens and reclassified them as art.

Early traders on the Northwest Coast saw these pieces as curios. They collected randomly, with untrained eyes, yet what they gathered leaves us spellbound. Almost without exception, pieces collected in the late eighteenth and early nineteenth centuries are of high quality. Clearly, the artistic level that prevailed at this time was extraordinarily high.

By 1820 the demand for curios had created a souvenir industry. Great quantities were turned out. The Northwest Coast people had known luxury during the height of the sea-otter trade and were reluctant to give it up. Curios were a poor substitute for sea-otter pelts, but there was little else to trade.

A distinct genre of almost identical masks was made between 1820 and 1870. Some are so similar as to be almost interchangeable. Most seem to be the work of three carvers. All have prominent, stationary labrets. Sailors wanted curios, especially human likeness showing lip distortion. I find most of them very dull. These souvenir masks are lifeless; all are well executed, but technique cannot conceal that meaningless quality everywhere characteristic of art without belief.

In the catalog for a show of northern art, 1973, three such masks are identified as shamans' masks and their painted designs interpreted as totemic clan emblems. But shamans' masks are quite different in form and generally much weathered, having been exposed on graves, whereas souvenir masks are often in mint condition, having seen no use. I suspect that the designs on the souvenir masks are largely meaningless. Cer-

Portrait mask of a woman with a labret. Haida, ca. late eighteenth century.

tainly they differ from traditional face and mask designs. A totemic emblem was a privilege, personal or family—not suitable for export. Souvenir masks were addressed to alien audiences. I'm reminded of a Dufy composition incorporating a musical score that can't be played; or an actor, playing a physicist, who doesn't put real formulae on the blackboard—unless he performs at M.I.T.

The first serious collector on the Northwest Coast was Captain James Cook, who in the late eighteenth century gathered ethnographic materials as part of his general fact-finding endeavors. Similar expeditions followed, including one from Spain and one from Russia. This tradition was continued by the American government's Wilkes Expedition, 1838–41, which collected throughout the Pacific, including Northwest Coast material. George Foster Emmons (1811–1887), a member of that expedition, must have been particularly interested in ethnography, for his home in Princeton was said to have been decorated with Polynesian and Northwest Coast objects, and a number of early museum acquisitions bear his name.

His son, Lt. George Thornton Emmons, USN (1852–1945), became *the* name in Northwest Coast collecting. Beginning very early, at Sitka, he collected in great quantity, including the contents of shamans' graves. The Tlingit themselves shunned these graves, believing that only the deceased shamans had possessed the power to control these sacred objects. Yet I find no record that Emmons's collecting disturbed the Tlingit, and it's certain he enjoyed a lifelong friendship with them.

He dedicated more than sixty years to placing on record the meaning of life to these northern seafarers. Neither he nor his Canadian counterpart, Charles F. Newcombe, a Victoria physician, ever profited financially from the tens of thousands of documented specimens they shipped to museums. They refused to sell to collectors and dealers. They trusted only museums and that trust was largely kept.

Emmons was one of a handful of men around the turn of the century who committed their lives to preserving, in every available medium, what remained of Indian culture. What couldn't be kept alive, they wanted to preserve in books, museums, photographs, even recordings and films. They did this under the umbrella of "science," although their personal motives were far more humanistic.

I had the good fortune to know a number of these men, several quite well. All were so remarkable, I've often wondered what shaped them. Most, I noticed, had strong fathers. Emmons's father, after serving on the Wilkes Expedition, led a detachment from the Willamette Valley to California; distinguished himself in the Civil War; raised the flag at Sitka in 1867; and rose to the rank of Admiral, commanding the Hydrographic Office and later the Philadelphia Navy Yard—facts not lost on the Tlingit, who accepted G. T. Emmons as the son of a noble warrior.

And all of these men—at least, those I knew—expressed affectionate memories of mothers whose esthetic, even mystic interests and affiliations were sharply at variance with the world of applied power in post-Civil War America.

Those two temperaments joined in these men, the first in arduous exploration and disciplined scholarship, the second in mystic and esthetic modes of thought. These latter were initially treated as subjects of study, but later openly acknowledged as personal persuasions. Consider Dr. John R. Swanton, author of precise, accurate studies of Northwest Coast mythology. When he retired from the Smithsonian, he circulated a letter to friends stating that, as a public servant, he hadn't thought it suitable to express private convictions, but now felt free to record his long-standing belief in extrasensory perception.

Emmons, I'm sure, would have understood. By choice, he lived between two worlds, at home in both but happiest in between, like a man attracted to a beach or tidal pool where contrasting elements meet and interact. Impeccable in dress and speech, conservative in politics, courtly in manner, he was a frequent guest at the White House where he pleaded the Indian cause with his friend Theodore Roosevelt. Yet his closest friend, between 1882 and 1888, was Shartrich, the famed Tlingit chief who, in the winter of 1852, led a war party over the Chilkat Pass, 300 miles into the interior to capture and burn the Hudson's Bay Company post at Fort Selkirk.

In his later years, Emmons spoke of the Tlingit as "we." It was no affectation. After retiring from naval service and leaving his home in Sitka, he returned at every opportunity to the Northwest Coast, making long trips by open boat to remote villages, always collecting art.

Of all the collectors on the Northwest Coast, Emmons was by far the most active and successful. His first shipment to The American Museum of Natural History numbered 2,775 specimens. This was quickly followed by 1,351 more. I estimate the number of catalogued Northwest Coast specimens in museums today at 115,000 to 125,000. Emmons was responsible for a significant portion of these—and a very high proportion of the finest. The remainder were largely assembled by—my notes list fifty—missionaries, traders, teachers, geologists, naval men, geographers, illustrators, and anthropologists.

Anthropologists were particularly active in gathering material for the

World Columbian Exposition, Chicago, in 1893, as well as for museum displays and study purposes. They often commissioned specimens from living artists, thus inadvertently creating a new type of specimen, the "anthropological specimen." This was consciously more traditional in form, but in craftsmanship came out of the souvenir industry. Distinctions between objects made for native use, for tourists, and for anthropologists became muddied.

Today nearly all surviving Northwest Coast material culture is in public hands. I can think of no other area in the world where this applies, at least to this degree. Emmons, Newcombe, and a few others deserve full thanks. Little escaped their efforts. A few pieces, especially in England, have been in private hands since they left the Coast long ago. Others remain in Indian hands, often out of sight.

But nearly all great Northwest Coast pieces, privately owned—and there are only a few—once bore museum numbers. They left museums through sale, trade, gift, fraud, theft. Most came out at a time when curators traded freely, sometimes not even recording transactions. They felt free to do so because, until about 1955, this material had no more market value than seashells or beetles. Much of it wasn't even recognized as Indian by the general public, to whom "Indian" meant what Frederic Remington painted. One result of all this subtracting and adding was that documentation often got separated from specimens. The one beneficial result was that specimens often became accessible.

Between 1910 and 1940, that is, between the time the great collections were assembled and the time artists discovered Northwest Coast art, only Emmons, Newcombe, and a handful of others maintained a deep interest in this subject. All were interested in art. Only a few had museum appointments and even they were regarded by professional anthropologists as working "outside" anthropology. Anthropologists had lost interest in material culture and had never been interested in art.

One other collector requires mention. Louis Shotridge (1886–1937), grandson of the Tlingit noble, Shartrich, was born in Klukwan, famed Tlingit citadel of tradition and art. When he was 19, he met the director of an American museum who was passing through Haines, collecting. The director bought a fine, old dagger from Shotridge and asked for more. More followed, to become, over the years, a small collection unparalleled in quality.

At what point the director devised the plan to have Shotridge infiltrate his own culture to obtain its treasures, the record doesn't show. In the beginning, he simply asked Shotridge to buy for him. Then he put him on staff. It was common practice then for a museum to employ an Indian as general helper and occasional lecturer—in Indian dress—to schoolchildren.

Shotridge was handsome, intelligent, friendly. He was married to a Tlingit woman of like virtues. Sitka, where he attended school, offered no opportunities. Haines, where he was living, was a military town left over from the Gold Rush. His father, a strikingly proud, handsome man in photographs, was an alcoholic. So were several uncles. Home was mud, boredom, alcohol. The museum offered an escape.

During the two years it took to fi-

Louis Shotridge, a Tlingit who collected coastal art for an American museum, lived in a fashionable house set apart from the squalor of Haines. His own label for this picture reads: "Museum Expedition, Field Headquarters."

nalize this employment, he toured the United States with Indian shows. Shotridge proved a great success, popular with children, a favorite of the press, the hunting companion of Theodore Roosevelt and John Wanamaker.

In 1915 Shotridge returned to Klukwan. His first report begins: "Upon my arrival in Chilkat . . . I proceeded in the usual way of obtaining information from the natives, which is to hire an informant."

Two photographs from this period are especially interesting. One shows a trim house set apart from the squalor of Haines. The second shows the interior of the house: immaculate, spare, with fashionable wicker furniture, including a coffee table complete with fresh pad of paper and sharpened pencil. Crossed tennis rackets lean against the table. Shotridge's caption reads: "Museum Expedition, Field Headquarters."

Shotridge had large purchasing funds. He had a still camera and a movie camera. The museum had made, to his specifications, a typewriter with phonetic typeface for recording Tlingit texts. John Wanamaker gave him a powerboat, the *Penn*, large enough for him to live aboard with his family while on collecting trips. Photographs show him in tweeds, always with a camera slung from his shoulder. He appears on horseback, driving a dogsled, piloting the *Penn*, always apart—in dress and manner—from his kinsmen. They called him arrogant. They still revile his name.

"I obtained [the Kaguanton Shark Helmet] . . . from the last of the house group. . . . When I carried the object out of its place no one interfered, but if only one of the true warriors of that clan had been alive the removal of it would never have been possible. I took it in the presence of aged women, the only survivors in the house where the old object was kept, and they could do nothing more than weep when the once highly esteemed object was being taken away. . . ."

He spent most of the next twenty years collecting on the Coast. He knew where pieces were and how to recognize the best. He offered large sums. But, even when accepted, these offers were resented, partly, I think, because Shotridge was Tlingit, but had "gone out."

"I am now the only right heir who is in a position to dispose of any or all of the objects if I chose to do so,

but it is not going to be an easy thing to take away the Bear Emblem. . . . My plan is to take the old pieces one at a time.''

Unlike Emmons, he didn't limit offers to pieces no longer in use or no longer valued. Offers he made in Klukwan greatly exceeded the sums he paid elsewhere for comparable pieces, yet were generally rejected. In the end, he tried to steal the Rain Screen and houseposts from the Whale House in Klukwan.

These particular pieces, by general consensus, were the Tlingit's greatest surviving treasures. Shotridge had promised them to the museum as early as 1906, laying claim to them on the grounds his father had been the Master of the Whale House. But Tlingit descent is matrilineal. Shotridge had no claim. He didn't even have the right to enter the Whale House, except by invitation.

First he offered $3,500. There probably wasn't $100 cash in all Klukwan at that time. He spoke eloquently, at great length, in the Whale House. He said that the museum would protect these treasures, that they belonged to the world and would forever reflect the glory of the Whale House. The answer was an unequivocal no.

Finally, with the museum's knowledge, he laid plans to steal the Rain Screen and houseposts while the men were away fishing. ''We plan to take this collection,'' he wrote, ''regardless of all the objections of the community.'' The reply: ''I am glad you have found a way to overcome the serious difficulties in obtaining full possession.'' But a ''gun went off,'' narrowly missing him. This traditional Tlingit custom, midway between execution and assassination, was no mere warning. Shotridge sponsored a feast to reestablish peace.

The Depression worsened and the museum let him go. He received no pension, merely a letter of regret. He was left without means or purpose in a hostile community. He mailed twelve pieces of beadwork to the museum, suggesting the staff might want to buy them if the museum didn't. They averaged less than $3.00 each. Only one was purchased. Another was lost.

Finally he got a job as inspector in the salmon canneries, actually a river guard. Nothing better illustrates his status than this despised job. But he had buried one wife. His second wife was ill. He had five children. He was ill. The last known photograph of him shows him beside a small, torn tent pitched in snow. He holds a blackened coffee pot over a wood fire.

The circumstances of his death are still discussed. At Klukwan, some say he was killed for taking treasures. At Sitka, some say he was killed for ordering a fisherman off the river. The official report states that he ''fell from scaffolding,'' breaking his neck. But there was no scaffolding where his body was found. He lay beside a little cabin he had built. Even if his death was an accident, that doesn't explain why he lay unattended for days, until a teacher took him to a hospital. I accept the Sitka version. But, however he died, he died an ''outlaw,'' unprotected by community codes.

An interesting story, but how relevant? If we judge Shotridge by his visible role, the bitterness at Klukwan can be understood, the museum forgiven, the man forgotten. But I think he was larger than these events.

When Shotridge was young, he had no interest in traditional Tlingit life. Even after he returned, his sympathies were elsewhere. But he was well trained, and when he documented a piece, he did a first-rate job. He found that the old speeches, associated with major pieces, were still remembered in all their detail and eloquence: proposals in council to commission a work of art, speeches made in reply, payments made for a work, speeches made when it was worn or displayed, the capture of a piece by enemies, their treatment of it, ransoming the work, and so on.

I know of no other record, in all the literature of anthropology, that carries the reader so far into alien modes of thought associated with art. Reading these lengthy reports, one soon realizes that the physical object was only part of a complex pattern, and at times could become almost irrelevant. Consider three minor incidents relating to the Whale House screen and posts: At a time when there was hunger in Klukwan, the owners rejected $3,500, but then left the screen exposed outside, where it weathered badly. More recently, I stopped two roughhousing children from damaging this screen during a feast in the Whale House. No one else seemed concerned, although shortly afterward they rejected an offer of $750,000 and ordered the dealer who made it to leave. One member of the Whale House, speaking in council, urged

that the screen and posts be sold: "What is it we Chilkat respect? Power and money. We hire artists. A Tsimshian made the Rain Screen for us. We bought it for prestige and power. We should sell it for the same reasons."

Art, like so much else in Tlingit life, was often used for power. It was even used as a weapon. Shotridge's efforts to acquire pieces still in use were interpreted as a bid for power and fought by the Tlingit at every turn. Gradually he lost interest. He spent long periods in areas where there was nothing to collect, seeking out recluses, blind elders living alone in otherwise abandoned camps, far up remote tributaries. He lived with them, listening. I find no evidence that he was encouraged in this, yet it was these trips that proved ethnologically most fruitful.

Much of the art he obtained was the very best. My impression is that very little great art ever leaves a tribe. Its owners burn it or let it rot before they let strangers see it or take it. In New Guinea I once saw a Sepik village burn in twenty minutes. After carrying infants and elders to safety, men tore walls and roofs open to take out hidden treasures. These were put on rafts, then quickly covered, but for a moment I glimpsed absolutely magnificent pieces. In Borneo and New Guinea I've entered abandoned settlements and seen the very finest treasures under rotting rafters. The elders who had remained behind to guard them had all died.

I think this was equally true on the Northwest Coast. Aside from the efforts of Emmons, Newcombe, and Shotridge, only chance permitted us to see truly great pieces. Many were lost in house fires. Others were deliberately destroyed. I don't think even the early explorers got the best, save for rare presentation pieces. Most of what passes for Northwest Coast art is mere merchandise, made for commoners, and souvenirs, made for us. The fact that even this material is generally good, in design and execution, encourages us to look no further.

In failing to look further, we sell this art short. There were masterpieces of the highest order on the Northwest Coast. The people on the Coast knew them, guarded them, needed them. The few now in our museums usually lie buried in storage or lost in bad lighting. But seen on their own terms, they can be recognized. They stand out. □

Additional Reading

Louis Pasteur (p. 8)

The best biography of Pasteur, according to René Dubos, is *Pasteur: The History of a Mind,* written in 1896 by Emile Duclaux, his collaborator and successor at the Pasteur Institute; a reprint of a 1920 translation is currently available (Metuchen: Scarecrow Press, 1973, $12.50). This almost psychological study provides a unique interpretation of the mind of Pasteur at work. An official biographical account, *The Life of Pasteur,* was produced in 1899 by René Vallery-Radot, Pasteur's son-in-law and secretary; the 1923 English translation has since been reprinted (Ann Arbor: Finch Press, $14).

Rain-making Forests (p. 22)

General information on the ecological processes characteristic of mountain and coastal forests in which "fog drip" occurs is found in a chapter entitled "The Mountain Roots" in *New England Wilds,* by Ogden Tanner (New York: Time-Life Books, 1974). Vogelmann's "Precipitation from Fog Moisture in the Green Mountains of Vermont" (*Ecology,* 1968, vol. 49, pp. 1205–1207) describes the methodology he and his colleagues used. Of particular interest to mountain or coastal residents wishing to experiment themselves is the "five and dime" equipment employed in these technologically advanced times to achieve such significant findings. (The author notes that in the study of Mexican coastal regions described in this issue a total of only $6.50 in supplies was required.)

County Donegal (p. 26)

Historian-geographer E. Estyn Evans, in his book *Irish Folkways* (Boston: Routledge & Kegan Paul, 1966, $6.50), traces modern practices in the Irish countryside as they evolved from the invasions and conquests of Ireland over the centuries. In contrast, anthropologists Conrad M. Arensberg and Solon T. Kimball, in their ethnographic account of one community in the west of Ireland in the 1920s, *Family and Community in Ireland* (2nd ed. Cambridge: Harvard University Press, 1968), present a contemporary picture of family and social relationships. A lucid discussion of Irish political history relative to the ecology of the land is found in A.R. Orme's *Ireland* (Chicago: Aldine Publishing, 1970). T.W. Freeman's *Ireland: A General and Regional Geography* (4th ed. New York: Barnes & Noble, 1972) presents a thorough discussion of County Donegal. R.N. Salaman's *The History and Social Influence of the Potato,* reissued in 1970 (Cambridge: Cambridge University Press), tells the absorbing story of this one plant, which figured so prominently in Irish history, tracing the importance of the potato crop to the survival of the Irish people during periods of conquest.

Antarctic Deep Divers (p. 36)

G.L. Kooyman's "The Weddell Seal" (*Scientific American,* 1969, vol. 221, no. 2, pp. 100–106) and Ian Stirling's "Ecology of the Weddell Seal in McMurdo Sound, Antarctica" (*Ecology,* 1969, vol. 50, pp. 573–586) provide background material on the biology, breeding cycles, and behavioral adaptations of these seals to their harsh environment. Comparable information on the emperor penguin is found in Jean Rivolier's "Polar Realm of the Emperor" (*Natural History,* 1959, vol. 68, no. 2, pp. 66–81) and in J.C. Deguine's photographic essay, *Emperor Penguin: Bird of the Antarctic* (Brattleboro: Stephen Greene Press, 1974).

Physiologist P.F. Scholander's "The Master Switch of Life" (*Scientific American,* 1963, vol. 209, no. 6, pp. 92–106) discusses the adaptations in the circulatory and respiratory systems of deep-diving animals that allow extended breath holding. G.L. Kooyman and H.T. Andersen's "Deep Diving," in *The Biology of Marine Mammals* (New York: Academic Press, 1968, pp. 65–94), edited by Andersen, details the diving physiology of seals and whales, while Kooyman's "Behavior and Physiology of Diving," in *The Biology of Penguins* (London: MacMillan Press, 1975, pp. 115–137), edited by B. Stonehouse, deals similarly with penguins as a group.

Carnivorous Baboons (p. 46)

Summaries of primate behavior are found in Alison Jolly's *The Evolution of Primate Behavior* (New York: Macmillan, 1972, $4.95) and Hans Kummer's *Primate Societies: Group Techniques of Ecological Adaptation* (Chicago: Aldine Publishing, 1971, $2.95). *Baboon Ecology: African Field Research,* by Stuart and Jeanne Altmann (Chicago: University of Chicago Press, 1970), is based on studies in Kenya in the early 1960s; this monograph presents the general background of the species and remains the most complete study available of baboons in their natural environment. Anthropologist R.A. Dart's "The Carnivorous Propensity of Baboons" (*Symposia of the*

Zoological Society of London, 1963, vol. 10, pp. 49–56) summarizes anecdotal accounts and authenticated cases of carnivorous behavior in southern African baboons. Geza Teleki presents evidence for meat eating as an important element of the natural history of another close relative of man in "The Omnivorous Chimpanzee" (*Scientific American*, 1973, vol. 228, no. 1, pp. 32–42). George Schaller and G. Lowther's "The Relevance of Carnivore Behavior to the Study of Early Hominids" (*Southwestern Journal of Anthropology*, 1969, vol. 25, pp. 307–341) is considered a key paper in the historical development of animal models of early human populations.

Northwest Coast Indian Art (p. 54)

Both *Northwest Coast Indian Art: An Analysis of Form*, by Bill Holm (Seattle: University of Washington Press, 1970, $4.95), and *Art of the Northwest Coast Indians*, by R.B. Inverarity (2nd ed. Berkeley: University of California Press, 1967, $7.95), give examples and analyses of Indian art. Haida Indian carver William Reid and photographer Adelaide De Menil interpret the work of the totem pole artisans in *Out of the Silence* (New York: Harper & Row, 1972, $4.95); the account was excerpted in the February 1972 issue of *Natural History* (vol. 81, no. 2, pp. 64–73). Polly and Leon Miller's *Lost Heritage of Alaska: The Adventure and Art of the Alaskan Coastal Indians* (Cleveland: World Publishing, 1967) tells of the men who first contacted the Indians and collected much of the art now displayed in museums and art collections.

The exhibition of Northwest Coast Indian Art described in *Form and Freedom*, by B. Holm and W. Reid (Houston: Institute for the Arts, Rice University, 1975), will be in Australia throughout 1976; in Toronto, at the Art Gallery of Ontario, from mid-January through March 1977; at the Seattle Art Museum in May and June 1977; in San Francisco, at the M.H. de Young Memorial Museum, from February through May 1978; and sometime after that at the Metropolitan Museum of Art in New York.

Gordon Beckhorn

ERRATUM: The December 1975 article "The Tea Mystique" erroneously stated that more tea than coffee is consumed each year in the United States. The statement should have read more tea than coffee is consumed *worldwide*.

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by Stanley A. Freed

The Cree's Day in Court

STRANGERS DEVOUR THE LAND, by Boyce Richardson. *Alfred A. Knopf, Inc. $12.50: 342 pp., illus.*

At the heart of Richardson's book is the classic conflict of the large modern industrial nation and the small traditional society. The government of Quebec regarded a huge hydroelectric project, to be undertaken on the land of some 6,000 Cree Indians and Inuit (Eskimo), as basic to the economic future of the province. The native people, many of whom hunted, trapped, and fished, feared that the project, which would flood some of their land and cause other ecological disturbance, would be destructive of their traditional culture. They went to court to halt the project.

Unabashedly partisan, Richardson casts the story in the now-familiar terms of the insensitive, perhaps wicked white man and the noble native. The project was "a ferocious onslaught" on native traditions. Richardson interprets the government's response to the native people's contention that the project would destroy their culture as saying in effect, "So the Cree would be destroyed? So what?" The white man can do nothing right. One would imagine that Richardson would see some value in modern education; the Indians did, to judge from their appointment of a 25-year-old man, presumably because of his education, as one of their three negotiators. Richardson comments, however, that the young man, although respectful of Indian values, had been "alienated from his culture by his many years of white man's schooling."

Couched in such terms, the book is designed to arouse emotions as much as to inform. The reader proceeds with a sense of foreboding, expecting to find in the last chapter the description of some disaster that had befallen the Cree and Inuit. Instead, one reads terms of a settlement that could easily be viewed as generous. Among its provisions, the settlement awarded the native people $150,000,000. They would also receive no less than 25 percent of the royalties that Quebec would receive from all development in the designated territory during the next 50 years, such royalties in each case to be payable for 20 years. The native people also achieved the major modification that they had requested, the relocation of a proposed dam. The government promised to provide a guaranteed annual income, higher than welfare benefits, for any native person who wished to hunt, trap, and fish as a way of life. It was the first guaranteed-income scheme for any Canadian group.

Guy Borremans

With considerable justification, some Indian leaders described the settlement as a victory. Nonetheless, Richardson insists on deriding not so much the settlement as the means by which it was achieved. "The native people had no choice but to settle with the government. Now they had merely to make the best of the agreement that was forced on them." The Indians themselves had a more realistic view. An Indian leader, announcing the settlement, said, "It has been a tough fight and our people are still very much opposed to the project, but they realize that they must share the resources [with the rest of the people of Quebec]. We believe that the agreement is the best way to protect our land from white man's intrusions. . . . We believe that this agreement guarantees the future of our children, and also that we can continue to live in harmony with nature."

Richardson's approach has disadvantages other than the arousal of emotions for an eventual letdown. First, he misses much of importance in the event. If the settlement was a victory for the 6,000 native people, it was also a victory for the 6 million people of Quebec. It has not been so very many years since even the best and most gentle Euro-Canadians and Euro-Americans did not question their right to appropriate Indian land. Against such a background, the settlement represents a growth of social conscience and considerable sensitivity to the rights and needs of a small minority. The legal processes of democratic countries have much in their favor.

A second disadvantage of the good versus evil approach is that the compromise and adjustment needed to solve stubborn problems, such as those of education, become more difficult. There are ways in which modern education does "alienate" people from traditional customs. To be a professional trapper and hunter, one must devote considerable time to learning the necessary skills as an adolescent. If these years are spent in school preparing for a career in aircraft maintenance or law, one is ill-prepared to live as a trapper. Modern education imparts values as well as technical skills. A traditional emphasis on generosity and sharing might be partially replaced by a concern for the accumulation of personal wealth. But is this situation a problem, and if so, what is the remedy? Would

Richardson seriously propose that native children be denied the opportunity to prepare for careers in the modern Canadian economy? Does he visualize an unchanging culture forever preserved on a reservation? Even were such a solution considered desirable, it would be impractical and, in the end, would fail.

Richardson, a journalist and film producer, has traveled and interviewed widely in native territory, and his account of the legal case is interspersed with many revealing vignettes of modern native life. Although the traditional aspects of native culture appeal to him most, the cultural and emotional complexity of the current situation is always apparent. From his interviews in Fort George, for example, Richardson detected "a curious ambivalence about the younger men, those working around town. . . . Most of them had excuses . . . for not being out on the land . . . family troubles and so on—and it was not being unduly skeptical to feel, as one of the journalists with me said, that 'if the times comes, I doubt if we will find them flocking back to the trapline. . . .' "

In Richardson's account, one hears not only echoes of traditional customs and values, but also, ever more insistently, the attitudes of the Western mercantile and industrial civilization that had its origins in the Middle East millennia ago, when the nomadic hunting ancestors of modern Indians were settling the New World. Behind some of the statements of Indian leaders, as they announced the settlement, one can almost sense the famous verse of Omar Khayyam.

Ah, take the Cash, and
let the Credit go,
Nor heed the rumble of a
distant Drum!

The native people of Canada and the United States have been the victims of injustice. They currently have special problems that merit the attention of the larger society. It is doubtful, however, that cultural and intellectual isolation will be the solution. For better or for worse, the native people of Canada and the United States are part of their nations and the world.

Stanley A. Freed is chairman and curator of the Department of Anthropology at The American Museum of Natural History.

by Beatrice M. Tinsley

Life and Death in the Milky Way

Chemical elements in our galaxy are made and recycled as stars are born, age, and die

The life story of our galaxy, the Milky Way, is the history of our cosmic ancestry. We ourselves are made of carbon, oxygen, nitrogen, iron, and dozens of other elements, which astrophysicists believe were cooked inside stars that lived and died in the Milky Way before the sun was born. Here we will consider some current ideas about the evolution of our galaxy and the origin of the elements.

To begin at the beginning: Most of the atoms in the Milky Way are hydrogen and helium, made about fifteen billion years ago in the explosive origin of our universe called the Big Bang (*see* "From Big Bang to Eternity?" *Natural History,* October 1975). The Milky Way began as a great ball of turbulent hydrogen and helium gas that first expanded, along with the universe around it; but within two billion years of the Big Bang, the ball contracted, under the attraction of its own forces of gravity, and collapsed. Some stars were born from the gas during the collapse, but most of the gas settled into a flat disk about 1,000 light-years thick and 100,000 light-years in diameter. There, over billions of years, the original galactic material undergoes evolutionary processes. The gas coalesces into clouds; deep inside these clouds, conditions are dense and cool enough for stars to be born. The stars separate from their parental clouds, and the leftover cloud material (which some astronomers call "placental") disperses into a diffuse gas, ready to be recycled into new stars or clouds.

Little by little, in this manner the gas in the Milky Way is turned into stars. By now about 80 percent of our galaxy's mass is in living stars or the corpses of dead ones. Our sun is a typical star, born, along with its planets, more than halfway through the life of the Milky Way.

We must now ask why the stars (and the solar system) are not made exclusively of hydrogen and helium from the Big Bang, but also contain small amounts of carbon, nitrogen, silicon, iron, and other elements. The question is important because without these heavier elements a solid earth would be impossible, and the complicated molecules that make up living things could not exist. The answer lies in the life—and death—of stars.

Each star spends most of its life at a rather steady size and luminosity on the so-called main sequence, which is a well-defined band on a diagram that plots luminosity against temperature. The main sequence contains stars up to fifty times as massive as the sun, with up to a million times the sun's luminosity, and stars that are less than 10 percent as massive as the sun and a thousand times fainter. Within the cores of main sequence stars, nuclear reactions take place that convert hydrogen into helium and release huge amounts of energy (these reactions are the same as those in hydrogen bombs). The energy is emitted by the stars as light, heat, and other forms of radiation.

The main sequence stage of a star's life lasts until all the hydrogen fuel near the star's center has been "burned" to helium. Because massive stars are so luminous, they radiate away their energy and use up their fuel much faster than smaller stars; therefore, although massive stars have more fuel to burn, they live on the main sequence for a much shorter time than small ones. For example, stars with more than five times the sun's mass (blue-white stars such as Spica in the constellation Virgo) live on the main sequence for only 100 million years or less. The sun, now 4½ billion years old, is halfway through its main sequence life. But stars with less than the sun's mass are still main sequence stars even if they were among the first to be born in the Milky Way.

Although 90 percent of a star's lifespan is spent in the staid main sequence stage, the stars' old ages and deaths are more important for the evolution of our galaxy. Less massive than our sun, the smallest stars, which neither mature nor die during the lifetime of our galaxy, affect its evolution by merely using up gas. At least half the mass of the Milky Way is locked up in such stars.

Those stars of a mass from just below that of the sun to five times greater swell up in old age to an enormous size and become red giants (exemplified by the red star Arcturus in the constellation Bootes). At that stage, they rapidly burn a lot more of their hydrogen into helium, then burn the helium itself into carbon by another set of nuclear reactions and, in some cases, burn part of the carbon into oxygen. Meanwhile, these red giants are blowing away their outer layers in a so-called stellar wind. Finally, more of the star is puffed off as a shell, called a planetary nebula (in small telescopes the diffuse green light of these shells resembles outer planets like Uranus).

In the centers of planetary nebulae are blue-white stars, which are the cores of what used to be red giants. These cores will become dead stars, or white dwarfs—corpses that cool over a few billion years from white heat to dim red to dark invisibility. Such will be the fate of our sun in six billion years, and such has already been the fate of some fifty billion other stars in the Milky Way.

Stars of a mass from that of the sun up to five times greater not only lock up matter in their corpses but also pour into our galaxy some new elements made during their lifetimes and shed in the stellar winds and planetary nebulae. These elements get mixed into the interstellar gas and are eventually condensed into clouds that give birth to new stars. So it is that later generations of stars (and their planets) contain the products of nuclear reactions that took place in stars of earlier generations.

In fact most of the supply of new elements in our galaxy is cooked in stars more than five times as massive as the sun. Such stars evolve from the main sequence into red supergiants

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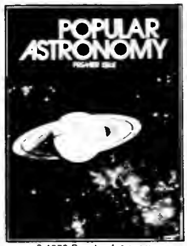

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(the great red star Betelgeuse in Orion is an example), bigger and brighter than the less massive giants and so much hotter inside that many more nuclear reactions occur within them. It is those reactions that build up the heavier elements.

The death of a massive star is a spectacular explosion known as a supernova. These violent detonations flare up in galaxies beyond the Milky Way and have also been recorded historically in our own galaxy. The debris from a supernova, including heavy elements cooked in the explosion and earlier during the quiescent life of the star, is strewn into the interstellar gas and eventually incorporated into later generations of stars.

The picture of the Milky Way's evolution that emerges from these stellar life histories is of a gradual loss of gas, which becomes locked into small living stars and the corpses of former larger ones, and enrichment of the remaining gas in elements cooked inside the biggest stars. Parts of the picture are verified by direct observations, other parts are hypothetical.

An obvious prediction is that the abundances of heavier elements in the interstellar gas should increase with time. Now, when we measure the amounts of heavy elements at the surfaces of stars (as revealed by details of the light they emit), we are not generally seeing the products of nuclear reactions going on in the stars themselves, but rather the composition of the gas from which the star originally formed. Thus we expect to see greater amounts of heavy elements on the surfaces of young stars than on old ones born early in the life of our galaxy. This prediction is indeed verified if we look at the very oldest stars, those made during the original collapse of our galaxy and now found far above its disk. But, surprisingly, it is impossible to detect any difference between the average heavy element abundance of the first stars formed in the disk after the collapse and those formed recently. Why do the disk stars show no evidence of the steady influx of new elements from dying stars? Astronomers have advanced several explanations.

One idea is that fresh gas, made only of hydrogen and helium from the Big Bang, has been raining down on the Milky Way from outside and diluting the interstellar material with unenriched gas as fast as stars pour in new elements. Radio astronomers do, in fact, find huge amounts of gas

moving toward the sun's part of the Milky Way, but there is disagreement as to whether this gas is falling in from intergalactic space or is simply moving around in the remote outskirts of our galaxy.

Another idea is that most of the heavy elements are not seen on the surfaces of stars because they are trapped in interstellar dust grains or even in comets (*see* "Missing Matter," *Natural History*, January 1976). Either or both of these suggestions may be right, but as yet, it is not clear what process has prevented the abundance of heavy elements from increasing perceptibly in interstellar space over billions of years.

We return now to the heavy elements in the sun and planets. Like most stars in the Milky Way, the sun is made of about 2 percent of heavy elements, cooked in earlier generations of stars, and 98 percent of primordial hydrogen and helium. Rocky planets such as the earth consist mostly of heavier material—the lighter atoms having been lost as these bodies formed. It is fascinating to reflect upon the origin of some of the atoms on earth that are essential to life, including human life. Iron, for example, is probably made during the supernovae explosions themselves. Carbon is made partly in the cores of stars that subsequently explode and partly in stars that release their products quietly in stellar winds and planetary nebulae. During the first billions of years of the Milky Way's history, many supernovae and many red giants must have contributed in those ways to the iron and carbon that eventually condensed into the earth as it was born beside the sun.

The life cycles of stars have thus made the history of the Milky Way. In birth, stars gradually use up the gas that once composed the whole galaxy; in death, they pour back some matter—enriched with new elements—which is mixed into the surrounding gas and used in later generations of stars. Many billions of years hence, there will no longer be enough gas in our galaxy to make new stars. The Milky Way will then shine for a while by the light of old stars, but they will snuff out one by one after their brillant old ages. In the end there will only be corpses of stars, fading to invisibility; the sun will be dead among them in its graveyard galaxy.

Beatrice Tinsley teaches astronomy at Yale University.

by Raymond Sokolov

Peace and the Ultimate Snack

Cultivated for past millennia, the well-tended olive is a sign of a prosperous future

Olives, as Mother used to say, are an acquired taste. I was eleven years old before I ever ate one with pleasure. Now you would have a hard time holding me back from a handful of these oily drupes. Green or black or red; pickled, oil soaked, shriveled—almost any kind will do. They are in many ways the world's best traditional snack.

To be more precise, of all the foods you don't have to cook before you munch, olives are the most interesting. Indeed, the cooked olive is unknown in most cuisines. The French add them cold and untampered with to a *salade niçoise.* They also stuff them with anchovy butter, make a paste, or *tapénade*, of them, and use them as a garnish on the Gallic pizza, the *pissaladière.* But the only major French dish that I can locate where the cooked olive is a central element is duckling braised with pitted, blanched olives.

Similarly, Italians in and around Perugia and Assisi spit-roast pigeons and then simmer them with wine and a mess of olives, which makes a dish of great sophistication. Then, too, Elizabeth David brought back a description of olive-stuffed escarole from her Italian wanderings (see recipe). But to find the olive cooked frequently as a matter of course, we must go to the Middle East.

This is, perhaps, unsurprising, since the cultivated olive (*Olea europaea*) originated in Asia Minor, began spreading westward in prehistoric times, and met with its greatest local success in North Africa. On the other hand, people like the Moroccans, who do cook olives habitually, engage in a somewhat paradoxical pursuit. The olive, you see, is already "cooked" before anyone cooks it.

I mean that olives are never eaten fresh off the tree. They are too bitter. They must be pickled first, with lye to remove the bitterness, then with salt to harden and preserve the flesh. Variations in the length of time the olive is exposed to lye or to salt account for some of the differences among the numerous types of olives sold in markets. Botanical variation is, of course, another factor. But the major source of pluralism in the olive world is a calculated result of human agriculture: the timing of the harvest makes the difference.

In the olive vats in Middle Eastern markets on Atlantic Avenue in south Brooklyn, you can get some sense of the range of olive colors and tastes. But anyone who has traveled in the Arab world or Israel will not have forgotten the festoons of olives in almost every color of the rainbow. The classic description is Paula Wolfert's, in her *Couscous and Other Good Food from Morocco:*

"There are stalls that sell nothing but olives—olives of every flavor, size, quality and color. An olive's color depends upon the moment in the ripening cycle that it is picked. As it ripens on the tree it turns from pale green to green-tan to tan-violet to violet-red to deep winy red to reddish black and finally to coal black. After that it loses its glistening appearance and begins to shrivel in the sun."

Moroccans, she continues, use three kinds of olives: (1) Barely ripe green olives, soaked in seven changes of brine and, finally, flavored with lemon juice. These are washed, drained, and boiled—at least three times—to remove bitterness before they are ready to "smother" a chicken. (2) Ripe or "midway" olives, ranging from tan to red to deep purple. These can be used direct from the vat after rinsing. And (3) smooth black olives. Moroccans do not eat olives at this stage and, instead, gobble salt-cured, shriveled black ones,


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which are often sold coated with a hot condiment. Sicilians have their own version of this peppery relish, and you can find it in some Italian stores in this country.

Most of these varieties of exotic olives are also available, mostly as imports, in fancy food outlets. The American olive industry has concentrated, although by no means exclusively, on the familiar green and black types. The first local trees were grown from Mexican seeds planted at the San Diego Mission. The resultant Mission olive that spread throughout California has not been identified with any European olive. At any rate, it throve in the clear, dry atmosphere and mild winter temperatures of California. Yet the fledgling West Coast olive industry suffered serious early reverses in the 1880s and 1890s. The major potential market, in the East, was not ready to absorb those first crops of ripe pickled olives. Orchards were uprooted and fifteen years went by before olive growers began once again to expand their plantings. Eventually, they perfected their techniques for producing the more marketable green olive; they were blessed with legislation that created a more competitive role for olive oil; and most important, easterners had learned to eat ripe olives. Furthermore, olivemen also concocted a preposterous system of boastful grading names that may entice some overly gullible consumers. But the most common effect of names such as giant, jumbo, mammoth, colossal, and supercolossal must be to confuse and alienate the rational shopper.

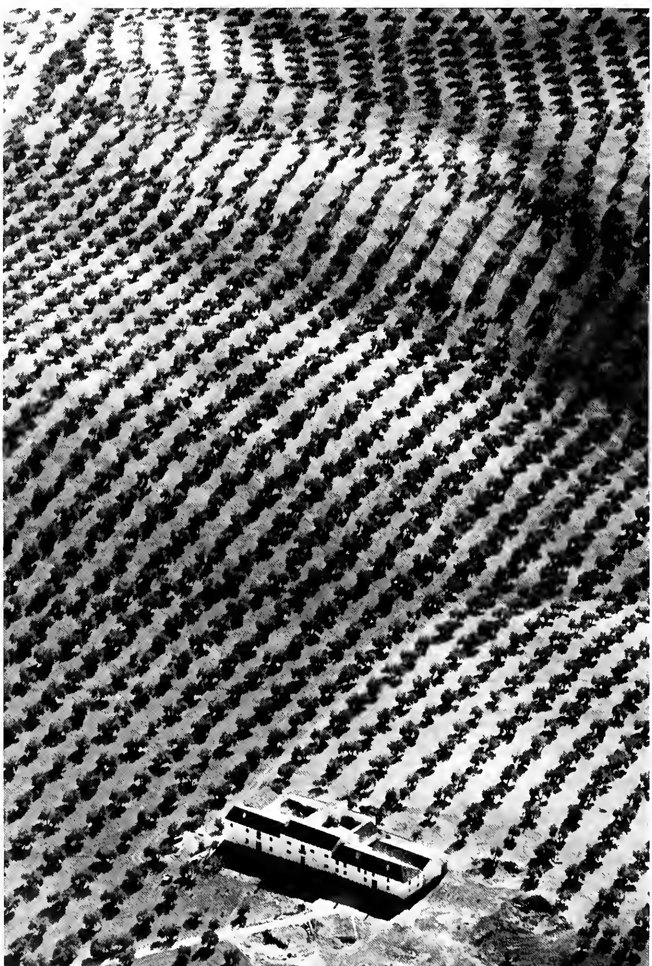
The simplest way to know what you are actually getting when you buy an olive is to shop in a specialty store that sells from open vats. That way you can see the size and you can taste several varieties before choosing. This sort of comparative olive tasting may, however, sabotage a well-laid diet plan, since salt-cured, oil-coated olives—the kind you are most likely to find in Mediterranean markets that still sell from open vats—are extremely high in calories. On the average, 100 grams (3½ ounces) of olives contain 338 calories, about as much as the same weight of angel food cake.

Olive oil itself is only a minor byproduct of the American olive industry. Of the 72,000 tons of olives produced here in 1973 (figures are preliminary, as listed in *Agricultural Statistics 1974*, the Agriculture Department's most recent edition), only 4,000 tons were crushed for oil. Other kinds of oil tend to be less troublesome: less prone to taste variation and more easily stored. Olive oil goes rancid in contact with air. It also burns at a lower temperature than salad oil.

Nevertheless, it is hard to imagine a more delicious taste than a mayonnaise created from high quality, golden olive oil, and a character of Mediterranean cooking is, to a certain extent, lost when, say, utterly bland peanut oil is substituted for the ancestral, limpid olive oil.

Fans of olive oil will go much further than that in their claims for its virtues. Western civilization, they will assert, was lubricated with olive oil. Greece and Rome both used it. Indeed, the word *oil* itself is related to the Latin for "olive." And, at least in Europe, the olive is a visible sign of continuity with the past. It is believed that some trees have been in place for almost 1,000 years. No one knows the maximum age an olive tree can attain. Italian highways circle respectfully around important groves of the gnarled, 25- to 40-foot-high evergreen trees, their roots sunk deep in the soil where they can tap water in time of drought.

It takes five or six years to grow a paying, fruit-producing tree and 25 or 30 years go by before a tree reaches its full growth. Severe pruning is the rule, and growers frequently harvest a tree only in alternate years, cutting



Olive plantation, Spain

George Gerster, Photo Researchers

it back sharply in the fallow year. Given fertile, deep soil, fair weather, and some water, an olive grower can face the future unafraid. More than most things, olives imply a feasible world to come. Perhaps that is why the olive branch symbolizes peace and the onward stretch of prosperity; not cataclysmic war with its promise of death and sudden endings. Put another way, by Shakespeare in an untypical English paean to our fruit of the month, "Peace proclaims olives of endless age."

Scarole Ripiene

(Stuffed Escarole, adapted from Elizabeth David's *Italian Food*)

1 handful breadcrumbs
12 pitted, chopped, medium black olives
8 anchovy fillets, drained, rinsed, and chopped
4 teaspoons capers, drained
3 tablespoons pine nuts (pignolia)
3 tablespoons currants, plumped in warm water and drained
3 cloves garlic, peeled and chopped
1 handful chopped parsley
7 tablespoons olive oil
Pepper
Salt
8 small heads of escarole or lettuce (a small Boston lettuce will do)
½ cup dry white wine

1. Combine breadcrumbs, olives, three-quarters of the anchovies, 1 teaspoon of the capers, the pine nuts, the currants, two-thirds of the chopped garlic, parsley, and 5 tablespoons of the olive oil to make the stuffing. Season with pepper and a little salt, if necessary.
2. Wash escaroles or lettuces and open out the leaves. Put some of the stuffing in the center of each. Fold the leaves back again and tie up each head with a string.
3. In a large heavy skillet, heat the remaining olive oil with the rest of the anchovies, garlic, and capers. Set the lettuces or escaroles in a single layer in the skillet. Add about a half-cup water. Cover and cook over very low heat for an hour or until the escarole or lettuce is tender.
4. Add white wine and cook, uncovered, for ten more minutes.

Yield: 8 servings

Raymond Sokolov is a free-lance food writer and novelist.

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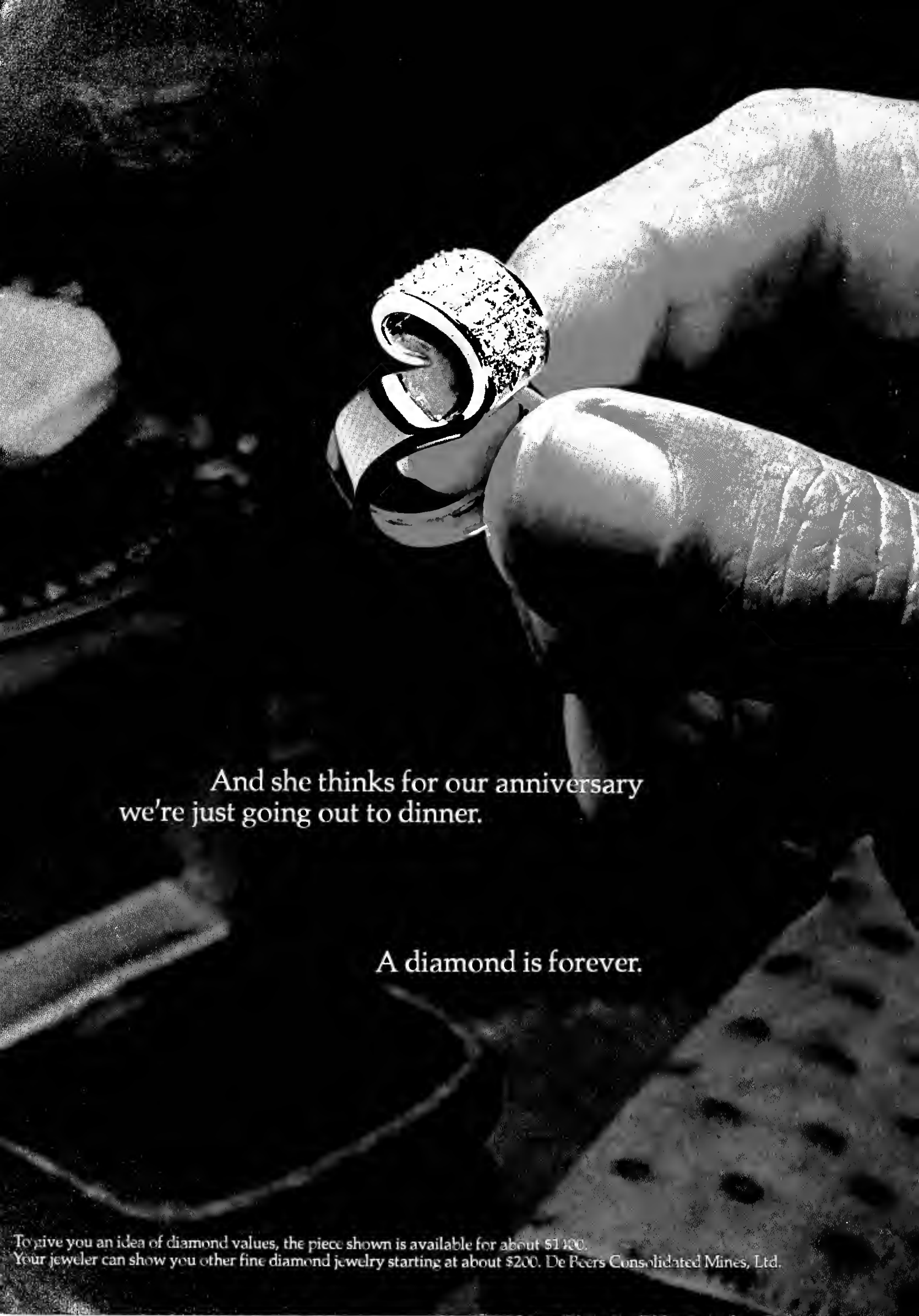

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NATURAL HISTORY

Incorporating Nature Magazine
Vol. LXXXV, No. 4
April 1976

The American Museum of Natural History
Robert G. Goelet, President
Thomas D. Nicholson, Director

Cover: *Near the end of the last Ice Age, painters in the Lascaux cave of France recorded the large animals of Europe's glacier-free regions. The aurochs, or wild ox, depicted in the painting was probably an important human food source at the time. Photograph by Jean Vertut. Stories, maps, and other cave illustrations on pages 56–69.*

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Authors

Traveling throughout Iran, and specifically to the ruins of Persepolis, has been essential to **Bernard Goldman's** research into the artistic origins of the Persian Empire. It was his study of the sculpture of those early times that prompted him to speculate on the use by the ancient Persians of art as a propaganda tool. Professor of Art History at Wayne State University in Detroit for the past ten years, Goldman hopes to turn his attention next to the Parthians and their role in the arts of the ancient East. A cache of gold unearthed in northwestern Iran was the subject of an earlier article for *Natural History,* "Shreds of Ancient Persia," May 1969.

After four years of laboratory research at Cornell University, **Paul A. Buckley** and **Francine G. Buckley** began looking in 1966 for a species of water bird that "presented provocative field problems." They found one—the royal tern—on Fisherman's Island, Virginia. Their investigation of this species' nesting patterns, crèche formations, and other behaviors took them to such places as Cape Hatteras, the Dry Tortugas, Puerto Rico, and the Netherlands Antilles. Paul Buckley is chief scientist with the National Park Service's North Atlantic Region, and an adjunct professor of environmental studies at the University of Massachusetts (Amherst). Coauthor and coresearcher Francine Buckley, who has worked on all of the royal tern projects, is planning to study the effects of human disturbance on habitat selection, breeding ecology, and reproductive success of various colonially nesting water birds.

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Trained at Charles University in Prague, geologist **George J. Kukla** first became interested in the Ice Age world twenty-five years ago when he found piles of ancient bones in the sediments of Czechoslovakian caves he was exploring. He has since studied Pleistocene sediments and ice formations around the world for evidence of past glaciations. A senior research associate at Lamont-Doherty Geological Observatory of Columbia University, Kukla is a member of CLIMAP, a joint project undertaken by several United States universities, which is investigating the climate of ice ages and interglacial episodes in order to learn what causes climatic shifts and how to prevent them.

Since his student days, when he worked at sorting Paleolithic bones in a university museum, **Dexter Perkins, Jr.,** has been interested in the relationship between prehistoric man and animals. Concentrating his studies on the early domestication of animals, he has examined examples of early man's art, which show evidence of domestication, as well as the skeletal remains of animals in Near East archeological sites. Perkins is at present classifying the thousands of animal bones found at Tep Godin, an archeological site in Iran with a 5,000-year history of expanding domestication. When not studying faunal remains, he teaches paleozoology at Columbia University.

Interested in the amount of space animals need, and the environmental components they require within that space, **Carol A. Simon** did a study of resource partitioning among Yarrow's spiny lizards. An assistant professor of biology at Ramapo College of New Jersey and an associate with the Department of Animal Behavior of The American Museum of Natural History, Simon did her field work at the Museum's Southwestern Research Station at Portal, Arizona. She first came to the station in 1964 as a student volunteer and went on to complete much of her postdoctoral work there. Simon plans to continue her research an territorial behavior and resource partitioning, as well as to examine the possible significance of licking behavior in lizards.

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by Richard M. Klein

The "Fever Bark" Tree

Quinine, the once-secret preparation made from the cinchona tree, was not only a remedy for malaria but also a pawn in the maneuvers of seventeenth-century kings and popes

Throughout man's troubled history, few diseases have played as significant a role as malaria. A retrospective romp through the past illuminates the impact of the disease.

In 1943, in World War II, perhaps as much as 15 percent of the American overseas army had malaria. In 1938–39, about 300,000 cases of malaria were recorded worldwide, including some 20,000 deaths in the Brazilian province of Rio Grande do Norte. The Spanish-American War in 1898 saw about four times as many troops incapacitated by malaria as by wounds. The Army of the Potomac under Union general George McClellan may have lost the offensive at Chickahominy in 1862 because it lacked enough healthy soldiers to oppose General Lee. The Pilgrims' decision in 1620 to settle in New England was made, according to William Bradford, long-time governor of Plymouth Colony, because "hott countries are subject to greevous diseases . . . and would not so well agree with our English Bodys." In 1596, the third earl of Cumberland captured Spanish Puerto Rico but was unable to hold it, probably because his forces were decimated by malaria. Rome was built on seven hills to avoid the malaria rampant in the adjoining valleys, and the city of Florence was depopulated in the second century B.C. by malaria, most likely introduced, via Sicily, from North Africa during the Punic Wars. Alexander the Great is thought to have died of it in June 323 B.C.

Among the twelve labors imposed on Hercules, the most famous of Greek legendary heroes, were the slaying of the nine-headed Hydra, the monster that brought human misery and ruin, and the shooting of the man-eating birds of the Stymphalian marshes. These are allusions to malarial infections that periodically swept through ancient Greece.

The name *malaria* was coined in the seventeenth century by a physician who combined the Italian words for "bad" and "air." The disease has also been called the shakes, the ague, the fevers, and many other things—none affectionate. Hippocrates, who was thought to have suffered the affliction himself, cogently noted that there were several clinical types of malaria, depending on whether the chills and fevers came every second or third day. He believed that imbalances in the ratios of the four humors—blood, phlegm, black bile, and yellow bile—caused the malady. Invisible worms, it was asserted for a thousand years, were carried on the dank night air into the body and were the penultimate cause of the illness.

And yet, the common people seemed to know that the mosquito was involved, for malaria was rare in dry and windy areas and disappeared during the winter, even from marshlands, when the insects vanished. From India, still an endemic malarial area, comes this lyric poem attributed to a fourth-century medical author:

> The green and stagnant waters
>   lick his feet
> And from their filmy, iridescent
>   scum
> Clouds of mosquitoes, gauzy
>   in the heat
> Rise with his gifts:
>   Death and Delirium.

It was not until 1880 that a French physician, Charles L. A. Laveran, found the microscopic, malaria-causing parasite in human red blood cells. And in 1898, the British bacteriologist Ronald Ross discovered the malarial parasite in the stomach wall of the *Anopheles* mosquito, thereby establishing the relation of the mosquito to the fevers. Both men subsequently received Nobel Prizes for their work. The complete life cycle of the *Plasmodium*, a genus of malarial parasite, was worked out in 1897–99. The existence of four major species of malarial parasites was soon discovered, and the need for mosquito control became so obvious that marsh draining and other control measures were widely adopted. DDT came into general use as an insecticide in the 1940s and in spite of what some now consider widespread overapplication, it saved thousands of lives. But it is impossible to kill all female mosquitoes, and even a few infected human beings can serve to initiate a fresh malaria cycle of epidemic proportions.

As far back as the fifteenth century, it was obvious that a chemotherapeutic agent effective against malaria was needed. One was found

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and its history starts in Lima, Peru, the sixteenth-century capital of New Spain. Lima became a city where riches were quickly amassed, and young Castilian gallants vied for permission to make an assured fortune from the mineral wealth so easily taken from the defeated Indians. The turnover of these hopeful merchant princes, however, was high because malaria was endemic in Peru. Yet, as the church fathers noted, the Indians in the bush were not excessively bothered by the disease. Through converts and slaves (usually one and the same), it was learned that on the eastern slopes of the Andes was a tree whose bark, when powdered and mixed with water, would cure the fever. The natives called the concoction made from the "fever bark" tree *quina quina*, literally "bark of barks."

An Augustinian monk in a book published in 1639 about his experiences in the New World remarked that the bark "cures the fevers and tertians," but the Augustinians were a contemplative and less worldly order than the Jesuits, and it was the Society of Jesus that recognized the political clout inherent in this light gray powder. Sending expeditions into the Andes, the Jesuits soon acquired a virtual monopoly of the supply of *quina quina* in Peru, Colombia, and Bolivia, and by various means they quickly turned their control into an official monopoly. At first they trickled *quina quina*, or quinine, back to Spain; later they systematically built up their markets through discreetly advertising that they, and they alone, could cure the fevers then sweeping across Europe. The Jesuits had little competition, for the standard treatment for malaria was still founded on Hippocrates' dicta of humors, and the best that could then be done for the already debilitated patient was bleeding, bed rest, and the application of cooling cloths.

The Society of Jesus formally decided that this wondrous bark should be employed for "the greater Glory of God and for good and useful Christians." With their imprimatur and the tacit approval of Pope Urban VIII, a treatise called *Schedula Romana*, which provided instructions in the use of the powder, was published in 1651. No Catholic physician then openly dared to oppose the use of quinine, although many were against it for a variety of reasons.

Meanwhile, Spanish galleons were lumbering back from the New World to their home ports with their holds laden with gold and silver bullion and bales of bark bearing the mark of the order. Malaria was decimating the French and English colonies tenuously established on the eastern seaboard of North America, and the buccaneers who plundered the Spanish Main were as welcome for their free-spending ways as for their loads of "Jesuit powder," as the fever bark was commonly called. Some was transshipped in good English bottoms back to Britain where the London ague, as the disease was known locally, was so feared. Jesuit powder was available, with directions for its use, at John Crook's London bookshop in 1658, but because of fears of a popish plot and possible curses placed on the remedy by "Jesuit devils," Oliver Cromwell, the Puritan lord protector of England, was not treated with the powder and died, presumably of malaria, the same year. The fear of using quinine for the protector came, in part, from the statement in a book by the eminent English physician Thomas Sydenham who asserted that the medicine attacked only the symptoms of malaria and could worsen the disease.

By 1660 the Jesuit distribution and control of quinine was breaking down. Several prominent persons had died after taking the powder, an unidentified fever in Rome in 1655 was not controlled by quinine, and the power of the Roman church to demand obedience and conformity had slipped. Physicians, only some of them Catholic, had long resented the high price the Jesuits exacted for their remedy, and with the Jansenist apostasy challenging the authority of the church, attacks on the Jesuit powder intensified.

Popular prejudice against the Society of Jesus was rallied by reformists and physicians, and supplies of quinine were becoming unobtainable because of piracy and slave revolts in Peru. According to some sources, however, a former apothecary's assistant in Essex, England, named Robert Talbor, could cure the ague by secret means. To quell fears, he announced that he was not a physician, but a feverologist, who by long and arduous study, "by observation and experimentation," had an exclusive and "certain method for the cure of this unruly distemper." He further announced, "Beware of all palliative cures, and especially that known by the name of Jesuit's powder, for I have seen most dangerous effects following the taking of that medicine."

By 1668 Talbor had moved to London where he set up a lucrative practice under the horrified noses of the Royal College of Physicians. Word of his cure soon spread to the court and when Charles II came down with malaria, the king called for Talbor.


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To cure her fever while living in Peru, the countess of Chinchóna, in this artist's representation, takes a proffered potion called quina quina. *The potion was made from the bark of a local tree subsequently named for the countess. The powder is known to us as quinine.*

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Engineered like no other car in the world.

Because of the suspicion that Talbor might use the hated popish remedy on the king, whose Protestantism was already suspect, loyal Englishmen carried placards warning that the Jesuits were going to poison the monarch. Happily, Charles recovered. In gratitude, he knighted Talbor, forced the College of Physicians to make Sir Robert a full member, and warned the outraged body that "you should not give him any molestation or disturbance in his practice."

Through Robert Talbor, Charles II saw a way in 1679 to improve the touchy relations then existing between England and France. The dauphin, son of King Louis XIV of France, suffered from periodic fevers, so Talbor was sent to Paris as a royal envoy with the title Physician to the King of England. Talbor's success in France was, if possible, even greater than in England. The entire imperial family was cured and Louis, as a royal gesture, sent Talbor to cure the queen of Spain. Appearances to the contrary notwithstanding, this was not really carrying coals to Newcastle; the Society of Jesus had recently been expelled from Madrid and the Jesuits had taken their powder with them. Once again, Talbor was successful. On his triumphal return to France, he changed his name to Talbot—then a distinguished French name—and joined the radical chic of Paris. Mme. de Sévigné referred to him as "un homme divin," and his bedside manner was most favorably commented on by the ladies of the court. As the Chevalier Talbot, and with malaria rife in Paris, he amassed a fortune. In 1680 he decided to return to England. Before Talbot left France, Louis XIV paid him three thousand gold crowns and promised him a lifetime pension in return for a sealed envelope containing a description of his secret remedy. Talbot/Talbor returned home covered with honor, became a fellow of St. John's College, Cambridge, and before his death in 1681, composed his own epitaph:

> The most Honorable Robert Talbor, Knight and singular physician, Unique in curing fevers of which he delivered Charles II of England, Louis XIV of France, the Most Serene Dauphin, princes, many a duke, and a large number of lesser personages.

Louis opened his expensive envelope in January 1682, and in a book

ascribed to him and entitled *The English Remedy or Talbot's Wonderful Secret for Curing of Agues and Feavers*, he revealed the secret. It was, of course, the hated Jesuit's powder mixed with wine to disguise the bitter taste of the alkaloid and using a different wine for each patient to confuse the issue. We still do not know how Talbor managed to secure his supply of quinine bark, but, according to him, it was not from the Jesuits. The discomfiture of the physicians who had denounced Talbor was great, but even with the identification of his secret cure, British medicine still refused to employ quinine. When Charles II had another bout of malaria in 1682–83, he literally had to beg his physicians for Talbor's remedy; they simply refused to admit that they had been outdone by a mere apothecary's apprentice.

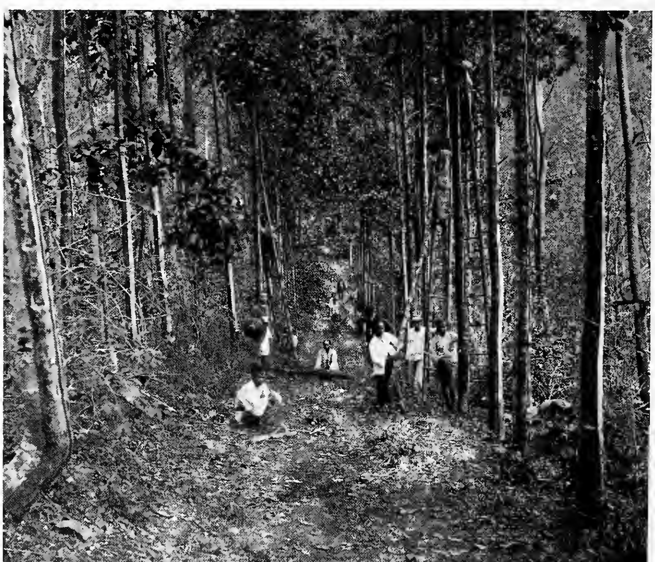
By the end of the seventeenth century, the dust had settled and quinine, no longer known as Jesuit powder, was the standard treatment for malaria in Europe and the Americas. Spain controlled the trade in the bark through its exclusive mandates in Peru and Bolivia, but it was evident that there were not enough wild trees to keep up with demand. This danger had been envisioned by the Jesuits a hundred years before when they attempted, unsuccessfully, to require that a new tree be planted for each one cut down. A French expedition, which studied the problem in the decade between 1730 and 1740, found that there were at least four major species of the fever bark tree. Specimens were sent to Linnaeus who, in honor of the wife of Count Chinchón, viceroy of Peru, gave the trees the genus name *Cinchona,* inadvertently dropping the first "h" in the count's family name. Subsequent collectors had to go farther and farther into the bush, getting lost, dying of disease, or being shot by the darts of local tribesmen. It became clear that the fever bark tree had to be grown as a plantation crop. In 1820, two young French chemists isolated the active alkaloid in the bark and standardization of the dosage soon followed. In 1849, seeds had sprouted in botanical gardens in England, France, and Holland and the public flocked to see the young trees. Thus, there appeared to be no barrier to plantation culture. Freedom from malaria for mankind seemed merely a matter of time.

Two countries dominated the race toward plantation culture—England, with its Ceylonese and Indian colonies, and Holland, with colonial control over much of the rest of Southeast Asia. The Dutch took the lead in 1845 when a Netherlands agriculturist started for Java with 400 young trees illegally smuggled out of Bolivia. But most of the trees died en route, and the seeds the smuggler had purchased at the same time came from a species low in quinine content. The agriculturist tried again in 1854, but after five years of growth, the young trees were virtually worthless. The Dutch tea planters in Java called the quinine operation "the governor general's hobby," and the taxpayers on the continent demanded an end to this folly.

In 1860, a British civil servant obtained seeds of the red cinchona tree from Peru for planting in Ceylon and India, but of the several million trees grown in those two countries, almost none contained economically useful levels of quinine in their bark. This fiasco cost the crown close to a half-million pounds sterling. A second planting of the red cinchona provided about 3 percent quinine. Unfortunately, these trees also had high concentrations of other, related but medically useless, alkaloids that required additional processing, so the growers still could not compete with the 10 percent yields obtainable from wild trees in South America.

The Bolivian quinine monopoly was finally broken in 1865 by an English bark trader named Ledger, who established his business in Puno, Peru, across Lake Titicaca from Bolivia. Knowing that the best bark was to be found only at high altitudes, he secretly sent his servant-translator in 1861 up into the Bolivian Andes near the headwaters of the Rio Beni where *Cinchona calisaya* trees with high-yielding bark were known to grow. The servant returned after a four-year stay with smuggled cinchona seeds for which Ledger paid £150. The precious seeds were shipped to London in the care of Ledger's brother and were offered first to the government of British India, which, having already been burned once, understandably refused them. The brother then went to Amsterdam and managed to sell some seeds to the Netherlands government and the Dutch East India Company for 100 gulden and a promise that an additional payment of 500 gulden would be made if the seeds were viable. An English planter bought the rest, but completely botched the job of cultivation.

The seeds sold in Holland reached



New York Public Library

Cinchona trees thrive on a quinine plantation in Java, where they were first successfully planted in the late-nineteenth century.

Java in December 1865, but on arrival they smelled so bad it was assumed that they had rotted in transit. Nevertheless, they were planted and, happily, they germinated well and the Ledger brothers received the promised additional payment. Over 10,000 trees were transplanted the following year and, by 1873, quinine plantations were established in Java. This time the Dutch East India Company took no chances. It sent a chemist to Java who methodically tested samples of the bark of each tree, marking for survival only those with yields of more than 13 percent quinine. These trees were used as grafting stock and the flowers were bagged so that the resultant seed remained genetically pure. By 1874 the superintendent of the Netherlands government plantations reported that within a few years there would be more than two million trees, each having bark with at least 8 to 9 percent quinine. And there were. In 1881, South America exported about nine million kilograms of bark, but in 1884, less than two million kilos found a market. The Dutch monopoly was essentially complete by 1890. After a few years of overproduction, controlled harvesting was achieved by 1910, and the world's supply of quinine was stabilized. This pattern was not altered until the Japanese overran the Javanese plantations in World War II.

With quinine under absolute monopolistic control in Java, many attempts were made to grow high-yielding trees in other parts of the world, but none were economically vigorous operations. Synthetic substitutes were accordingly sought. The Winthrop Chemical Company in the United States began experimenting with the antimalarial drug atabrine in 1931. But it tended to turn the skin a strange shade of yellow and its dosage was poorly understood so natural quinine was preferred. Not until the outbreak of the Second World War in 1939, and especially the campaigns in North Africa and the fall of the Philippines in 1942, did the quinine crisis spur the lagging efforts to synthesize effective antimalarials. Insecticides and other mosquito control measures and several safe and potent antimalarials developed during and after the war have since provided us with reasonable freedom from malaria.

Richard M. Klein teaches botany at the University of Vermont.

Letters

Of Human Bonds

In his article "Human Babies as Embryos" [February 1976], Stephen Jay Gould writes about the peculiarity of human babies being born helpless and undeveloped in comparison to other primates.

Alexander Pope noticed this feature of newborns and suggested in *An Essay on Man* that it was on this long-term weakness that the human family was founded, and that this very helplessness brought about monogamy and permanent family bonds:

> A longer care Man's helpless
> kind demands;
> That longer care contracts
> more lasting bands:
> Reflection, Reason, still the
> ties improve,
> At once extend the interest,
> and the love.

Our wants, weaknesses, and frailties, which create the bond between us as humans, create the moral fabric of compassion (what remains of it) that sustains society. Sometimes the social consequences of a simple fact like this one—the altricial features of the human newborn—can be overlooked by scientists.

Anne Barbeau
New York, New York

Agents of Extinction

Michael J. Bean's review of *The Politics of Extinction,* by Lewis Regenstein [January 1976] contained some irritating, misleading statements. Among these, the author repeats an old and false antihunting myth, namely, that "it is the hunters themselves who are principally responsible for the near obliteration of predatory animals such as the wolf, cougar, bear, and numerous others." The decline of the wolf, cougar, and bear is due, not to sport hunters, but to the forces of "civilization," especially the professional bounty hunting and strychnine baiting carried out to benefit ranchers and sheepherders and the general loss of habitat inevitable with our spreading population.

Loss of habitat and environmental pollution seem to be the main threats to wildlife populations in modern times, yet Bean devotes nearly half of his review to the hunting controversy. Clearly, the modern sport hunter is not an agent of extinction in his hunting activities. The hunter and the rest of us are agents of wildlife extinction in our activities as consumers, polluters, and propagators of the human race.

K. Allen Bowser
Lewisberry, Pennsylvania

Rice Connection II

I read the December 1975 issue enroute to a meeting of agricultural experts at the Asian Development Bank in Manila. My colleagues there were all much interested in the story on the aquatic fern *Azolla* ("The Water Fern–Rice Connection"), new to them, harboring a blue-green alga capable of fixing nitrogen.

Later I saw a rice paddy at the International Rice Research Institute near Manila, in which the fern, collected in the Philippine mountains, was growing. According to their experience thus far, it is capable of fixing some 60 kilograms of nitrogen nutrient per hectare, a remarkable performance. However, its survival seems to depend on a high phosphate content in the soil, so high as to make it of doubtful commercial value except in naturally phosphatic areas, as the North Vietnamese zone referred to in your article must be.

Let us hope that plant breeders can create new varieties unaffected by this limitation. It would represent an enormous advance in cost-efficiency, simplicity, and productivity for this basic Asian staple, to say nothing of the saving of fossil-fuel energy now required to produce artificial nitrogen fertilizer.

Edwin M. Martin
Washington, D.C.

The Delicate Okavango

Christopher Scholz has captured the magic of an unbelievable corner of the world in his article "Rifting in the Okavango Delta" [February 1976]. When my wife and I first saw this area in 1966, we knew we would have to return for a closer look. Thus, when we left our Peace Corps service in Malawi in 1968, we made a cross-country trek to Botswana. We camped for some time on the edge of the Okavango and then canoed in the area. We were treated to the sights of lily trotters making their way across the floating leaves and small insect traps on the bladderworts, just to mention two of the thousands of unbelievable treasures to be found in the Okavango.

After crossing the Kalahari, I settled at Kanye, Botswana, to teach secondary school for a brief period. I thus learned to share some of the problems and aspirations of the people of Botswana as they develop the resources of their country. I fear, however, as Scholz indicates at the close of his article, that there is an inherent conflict between development and the delicate ecological balance in the Okavango. I only hope that a compromise can be reached that will preserve some of the magic of this unique feature for future generations.

Bruce J. Hargreaves
New York, New York

Meaty Questions

In his column "A Steak in the Future?" [February 1976], Raymond Sokolov acknowledges that the production and consumption of meat protein is perhaps the least economically viable means of feeding the world's population, but then goes on to claim, "I doubt that I would make a dent in the worldwide trend toward ever higher meat consumption if I embarked on a program of acorn eating . . . or some other nonmeat diet." He ends his apology with, "In the meantime, I prefer to stifle my guilt, eat a corned beef sandwich now and then, and do my evangelical best to prevent my own species from exterminating itself through war."

The truth is that as many people are being exterminated through starvation and indifference as through war, and if Mr. Sokolov is genuinely concerned with the welfare of persons throughout the world, he would do well to reconsider his stand. For although we may not be individually capable of solving global political problems, we are individually and collectively responsible for alleviating whatever animal and human suffering we can. It is not a question of either sentimentality or taste but of serious moral reflection.

Mr. Sokolov's column gives us more tripe than is called for in his recipe.

Alan and Judith Tormey
Baltimore, Maryland

Although I agree with Raymond Sokolov that in the United States raising cattle for consumption is wasteful and sadistic, I was shocked that he would label the Hindu practice of cow worship as "masochistic" and therefore equally reprehensible. India's problem of starvation is not caused by cow worship, but quite possibly is the result of private ownership of large tracts of good land, which leaves the majority of the people landless and hungry. The Indian people will only begin to solve this problem when the land is cooperatively worked and food is distributed on the basis of need, not profit.

T. Bell
Brooklyn, New York

I enjoyed very much Raymond Sokolov's "A Steak in the Future?" I agree that meat is neat and that cows are incredibly stupid. Living off other life forms is just the way it breaks on this planet. I personally feel that vegetables have feelings, too. I've known weeds with more cunning than cows. I tend to apologize to kohlrabi when I cut it.

Having moved to the country, I try to raise as much as I can of what I eat. And there is all the difference in the world between home-grown and store-bought meat. As far as cruelty goes, my cows are treated really well, living in cow nirvana until the coup de grâce. I wish I could say it was reciprocal, but cows have just about done me in emotionally. They break through expensive new fences, eat whole stands of roasting ears at a gulp, clean out tomato plants in a guzzle. They ate the wiring out of the lawn mower and devoured my son's school notebook. ("Dear Mrs. Brown: You aren't going to believe this, but. . . .") They explore. I came home one day to find a cow eating the flower arrangement on the coffee table.

I will enjoy every morsel of those cows. They have given me a whole new insight into the primitives' ceremonial cannibalism of their enemies and liberated me to guilt-free eating.

Gay Weeks Neale
Meredithville, Virginia

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by Stephen Jay Gould

Ladders, Bushes, and Human Evolution

The jaws and teeth uncovered by Mary Leakey in Tanzania are one of the greatest fossil discoveries of the decade

My first teacher of paleontology was almost as old as some of the animals he discussed. He lectured from notes on yellow foolscap that he must have assembled during his own days in graduate school. The words changed not at all from year to year, but the paper got older and older. I sat in the first row, bathed in yellow dust, as the paper cracked and crumbled every time he turned a page.

It is a blessing that he never had to lecture on human evolution. New and significant prehuman fossils have been unearthed with such unrelenting frequency in recent years that the fate of any lecture notes can only be described with the watchword of a fundamentally irrational economy—planned obsolescence. Each year, when the topic comes up in my courses, I simply open my old folder and dump the contents into the nearest circular file. And here we go again.

A front-page headline in the *New York Times* for October 31, 1975, read: "Man traced 3.75 million years by fossils found in Tanzania." Dr. Mary Leakey, unsung hero of the famous clan, had discovered the jaws and teeth of at least eleven individuals in sediments located between two layers of fossil volcanic ash dated at 3.35 and 3.75 million years, respectively. (Mary Leakey, usually described only as Louis's widow, is a famous physical anthropologist whose credentials are more impressive than those of her flamboyant late husband. She also discovered several of the famous fossils usually attributed to Louis, including the "nutcracker man" of Olduvai, *Australopithecus boisei*, their first important find.) Mary Leakey classified these fragments as the remains of creatures in our genus *Homo*, presumably of the East African species *Homo habilis*, first described by Louis Leakey.

So what? In 1970, Harvard paleontologist Brian Patterson dated an East African jaw at 5.5 million years. True, he attributed the fragment to the genus *Australopithecus*, not to *Homo*. But *Australopithecus* has been widely regarded as the direct an-

Wide World Photos

Mary Leakey presents the skull of Australopithecus boisei, *found in 1959, to President Nyerere of Tanzania.*

British Columbia, Canada.

These pictures are just a sample of what is waiting for you in British Columbia. 1. One of many intriguing shops that can be found throughout the Province. 2. Long Beach on Vancouver Island, 11 miles of unbroken beach on the Pacific Ocean. 3. The Williams Lake Stampede. Dozens of rodeos take place all summer long in British Columbia's cattle country. 4. An outdoor restaurant in Gastown, the original settlement of British Columbia's largest city, Vancouver. For more pictures and lots more information write: British Columbia Department of Travel Industry, 1019 Wharf Street, Victoria, British Columbia V8W 2Z2. Or see your local travel agent.

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cestor of *Homo.* While taxonomic convention requires the award of different names to stages of an evolving lineage, this custom should not obscure biological reality. If *H. habilis* is the direct descendant of *A. africanus* (and if the two species differ little in anatomical features), then the oldest "human" might as well be the oldest *Australopithecus,* not the oldest recipient of the arbitrary designation *Homo.* What, then, is so exciting about some jaws and teeth a million and a half years younger than the oldest *Australopithecus*?

I believe that Mary Leakey's find is the second most important discovery of the decade. To explain my excitement, I must provide some background in human paleontology and discuss a fundamental, but little appreciated, issue in evolutionary theory—the conflict between "ladders" and "bushes" as metaphors for evolutionary change. I want to argue that *Australopithecus,* as we know it, is not the ancestor of *Homo;* and that, in any case, ladders do not represent the path of evolution. (By "ladders" I refer to the popular picture of evolution as a continuous sequence of ancestors and descendants.) Mary Leakey's jaws and teeth are the oldest "humans" we know.

The metaphor of the ladder has dominated most thinking about human evolution. We have searched for a single, progressive sequence linking some apish ancestor with modern man by gradual and continuous transformation. The "missing link" might as well have been called the "missing rung." As the British biologist J. Z. Young recently wrote (1971) in his *Introduction to the Study of Man:* "Some interbreeding but varied population gradually changed until it reached the condition we recognize as that of *Homo sapiens.*"

Ironically, the metaphor of the ladder first denied a role in human evolution to the African australopithecines. *A. africanus* walked fully erect, but had a brain less than one-third the size of ours (see my column of November 1975). When it was discovered in the 1920s, many evolutionists believed that all traits should change in concert within evolving lineages—the doctrine of the "harmonious transformation of the type." An erect, but small-brained ape could only represent an anomalous side branch destined for early extinction (the true intermediate, I assume, would have been a semierect, half-brained brute). But,

as modern evolutionary theory developed during the 1930s, this objection to *Australopithecus* disappeared. Natural selection can work independently upon adaptive traits in evolutionary sequences, changing them at different times and rates. Frequently, a suite of characters undergoes a complete transformation before other characters change at all. Paleontologists refer to this potential independence of traits as "mosaic evolution."

Secured by mosaic evolution, *A. africanus* attained the exalted status of direct ancestor. Orthodoxy became a three-runged ladder: *A. africanus–H. erectus* (Java and Peking Man)–*H. sapiens*.

A small problem arose during the 1930s when another species of australopithecine was discovered—the so-called robust form, *A. robustus* (and later the more extreme "hyper-robust," *A. boisei*, found by Mary Leakey in the late 1950s). Anthropologists were forced to admit that two species of australopithecines lived contemporaneously and that the ladder contained at least one side branch. Still, the ancestral status of *A. africanus* was not challenged; it merely acquired a second and ultimately unsuccessful descendant, the small-brained, big-jawed robust lineage.

Then, in 1964, Louis Leakey and his colleagues began a radical reassessment of human evolution by naming a new species from East Africa, *Homo habilis*. They believed that *H. habilis* was a contemporary of the two australopithecine lineages; moreover, as the name implies, they regarded it as distinctly more human than either of its contemporaries. Bad news for the ladder: three coexisting lineages of prehumans! And a potential descendant (*H. habilis*) living at the same time as its presumed ancestors. Leakey proclaimed the obvious heresy: both lineages of australopithecines are side branches with no direct role in the evolution of *Homo sapiens*.

But *H. habilis*, as Leakey defined it, was controversial for two reasons. The conventional ladder could still be defended:

1. The fossils were scrappy and came from different places and times. Many anthropologists argued that Leakey's definition had mixed two different things, neither of which was a new species: some older material properly assigned to *A. africanus*,

and some younger fossils belonging to *H. erectus*.

2. The dating was insecure. Even if *H. habilis* represented a valid species, it might be younger than most or all of the known australopithecines. Orthodoxy could become a four-runged ladder: *A. africanus–H. habilis–H. erectus–H. sapiens*.

But, as a new consensus began to coalesce about the expanded ladder, Louis and Mary Leakey's son Richard reported the find of the decade in 1973. He had unearthed a nearly complete skull with a cranial capacity near 800 cc, almost twice that of any *A. africanus* specimen. Moreover, and this is the crucial point, he dated the skull at between 2 and 3 million years, with a preference for something near the older figure—that is, older than most australopithecine fossils, and not far from the oldest, 5.5-million-year date. *H. habilis* was no longer a chimera of Louis's imagination. (Richard Leakey's specimen is often cautiously designated only by its field number, 1470. But whether or not we choose to use the name *Homo habilis*, it is surely a member of our genus, and it is just as surely a contemporary of *Australopithecus*.)

Mary Leakey has now extended the range of *H. habilis* back another million years (perhaps closer to 2 million years, if 1470 is closer to 2 than to 3 million years old, as many experts now believe). *H. habilis* is not the direct descendant of known *A. africanus;* the new finds are, in fact, older than almost all specimens of *A. africanus* (and the taxonomic status of all fragmentary specimens older than Mary Leakey's *H. habilis* is in doubt). Based on the fossils as we know them, *Homo* is as old as *Australopithecus*. (One can still argue that *Homo* evolved from an older, as yet undiscovered *Australopithecus*. But no evidence supports such a claim, and I could speculate with equal justice that *Australopithecus* evolved from an unknown *Homo*.)

Chicago anthropologist Charles Oxnard has just dealt *Australopithecus* another blow from a different source. He studied the shoulder, pelvis, and foot of australopithecines, modern primates (great apes and some monkeys), and *Homo* with the rigorous techniques of multivariate analysis (the simultaneous statistical consideration of large numbers of measures). He concludes that the australopithecines were "uniquely dif-

ferent" from either apes or humans, and argues for "the removal of the different members of this relatively small-brained, curiously unique genus *Australopithecus* into one or more parallel side lines away from a direct link with man."

What has become of our ladder if there are three coexisting lineages of hominids (*A. africanus*, the robust australopithecines, and *H. habilis*), none clearly derived from another? Moreover, none of the three display any evolutionary trends during their tenure on earth: none become brainier or more erect as they approach the present day.

At this point, I confess, I cringe, knowing full well what all the creationists who deluge me with letters after each column must be thinking. "So Gould admits that we can trace no evolutionary ladder among early African hominids; species appear and later disappear, looking no different from their great-grandfathers. Sounds like special creation to me." (Although one might ask why the Lord saw fit to make so many kinds of hominids, and why some of his later productions, *H. erectus* in particular, look so much more human than the earlier models.) I suggest that the fault is not with evolution itself, but with a false picture of its operation that most of us hold—namely the ladder. Which brings me to the subject of bushes.

I want to argue that the "sudden" appearance of species in the fossil record and our failure to note subsequent evolutionary change within them is the proper prediction of evolutionary theory as we understand it. Evolution usually proceeds by "speciation"—the splitting of one lineage from a parental stock—not by the slow and steady transformation of these large parental stocks. Repeated episodes of speciation produce a bush.

How does speciation occur? This is a perennial hot topic in evolutionary theory, but most biologists would subscribe to the "allopatric theory" (the debate centers on the admissibility of other modes; nearly everyone agrees that allopatric speciation is the most common mode). *Allopatric* means "in another place." In the allopatric theory, popularized by Ernst Mayr, new species arise in *very small* populations that become isolated from their parental group at the *periphery* of the ancestral range. Speciation in these small isolates is *very*

rapid by evolutionary standards—hundreds or thousands of years (a geologic microsecond).

Pressures of natural selection tend to be intense in geographically marginal areas where the species barely maintains a foothold. Favorable genetic variation can quickly spread through these reduced populations. In large central populations, on the other hand, favorable variations spread very slowly, and most change is steadfastly resisted by the well-adapted population. Small changes occur to meet the requirements of slowly altering climates, but major genetic reorganizations almost always take place in the small, peripherally isolated populations that form new species.

If evolution almost always occurs by rapid speciation in small, peripheral isolates, then what should the fossil record look like? We are not likely to detect the event of speciation itself. It happens too fast, in too small a group, isolated too far from the ancestral range. Only after its successful origin will we first meet the new species as a fossil—when it has reinvaded the ancestral range and become a large central population in its own right. During its recorded history in the fossil record, we should expect no major change. We know it only as a successful central population. It will participate in the process of organic change only when some of its peripheral isolates speciate to become new branches on the evolutionary bush. But it, itself, will appear "suddenly" in the fossil record and become extinct later with equal speed and little perceptible change in form.

The fossil hominids of Africa fully meet these expectations. We know about three coexisting branches of the human bush. I will be surprised if twice as many more are not discovered before the end of the century. The branches do not change during their recorded history, and if we understand evolution aright, they should not—for evolution is concentrated in rapid events of speciation, the production of new branches.

Homo sapiens is not the foreordained product of a ladder that was reaching toward our exalted estate from the start. We are merely the only surviving branch of a once luxuriant bush.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

by Arthur W. Galston

How Safe Should Safe Be?

The screening of new herbicides and other synthetic compounds must be expanded to include the possibly mutagenic effects of their metabolic by-products

Modern industry, agriculture, and medicine float on a sea of synthetic chemical compounds. Every year thousands of such new products are devised. Each purports to solve some human problem or satisfy some human need better than its predecessors. Some are uneconomic to make and never reach the production line or sales counter. Others are weeded out between the testing laboratory and the production line because they are obviously dangerous or toxic to human life. But even those that get through the screens imposed by private companies and the various local, state, and federal agencies, cannot automatically be considered safe. In fact, an alarming number of compounds and processes, long accepted and used, have recently been found to have unexpected and deleterious effects on biological systems. Thus it has become imperative to inquire closely into the criteria that are, and ought to be, employed to safeguard the public health and well-being: continually to explore the question, How safe should safe be?

Developing these criteria is not entirely an exercise in rational, dispassionate analysis. More and more, the process involves reconciling the often conflicting interests of business, agriculture, and the environmentalists. Known benefits are carefully weighed against demonstrated or possible side effects. The final choices are both subjective and evaluative. DDT is an example. The fact that it can wipe out malaria-bearing mosquitoes must be balanced against its inadvertent destruction of useful insects, such as bees and others serving as sources of food for birds. Similarly, the drop in crop productivity and loss of income that result from the banning of DDT must be balanced against the possibility that its slow biodegradability may ultimately produce new dangers to man. There are still unanswered questions concerning DDT, but while they are being worked out, countries where insect-borne human diseases are still a major problem cannot be expected to ban the compound.

Against this background, a recent discovery by two brand-new Ph.D.s is of particular interest, for by applying a known but neglected approach to the testing of herbicides, they have raised doubts about the alleged safety of most agricultural chemicals in major use today. Michael J. Plewa of the Department of Agronomy of the University of Illinois and James M. Gentile of the Department of Human Genetics at Yale University have just produced evidence that atrazine, the most widely used herbicide in cornfields, gives rise to metabolic products that cause mutations, and possibly cancer, in laboratory animals. Independent substantiation of their claims, which appears to be at hand, could lead to a massive reappraisal of the procedures normally employed for certifying as safe those chemicals designed to be used in agriculture.

How could such a pernicious effect have been overlooked when atrazine was first tested? Atrazine itself, produced by Ciba-Geigy, a Swiss-based corporation, had a clean bill of health. When fed to experimental animals for detection of toxicity symptoms, to microorganisms for detection of mutagenicity, and to tissue cultures for detection of possible carcinogenicity (by induction of cancerous overgrowths), atrazine was innocuous. If it is first supplied to corn plants, however, chemical extracts of the leaves and kernels of such plants

show mutagenic activity in appropriate biological test systems. Corn plants not treated with the atrazine do not produce such symptoms. The inference is clear: although itself innocuous, atrazine is transformed by the corn plant into a substance that can cause genetic aberrations. While it has long been recognized that the metabolic products of herbicides, as well as the herbicides themselves, should be tested for toxicity in various organisms, this procedure has not been conscientiously followed with most major compounds.

The results found by Plewa and Gentile have been published in brief and preliminary form in the *Maize Genetics Cooperative Newsletter* and will shortly appear in full form in the monthly journal *Mutation Research*. In the meantime, both the federal Environmental Protection Agency and the National Institute of Environmental Health Sciences, part of the National Institutes of Health, have manifested considerable interest in funding a continuation of this study. What makes it so convincing to experts in the field is that these researchers have devised a procedure for detecting possible herbicide mutagenicity within the crop plant itself as well as in microbial test organisms.

To test the mutagenicity of the herbicide directly on the crop plant, Plewa and Gentile used a genetically pure *waxy* corn plant, itself a mutation from standard corn. The gene for waxiness also inhibits the production in the plants of the starch component amylose, made by nonmutant corn. *Waxy* corn produces instead only a related material, amylopectin. Amylose stains a deep blue when exposed to a mixture of iodine and potassium iodide, but amylopectin stains a faint tan. This characteristically different color response to the same reagent applies even in the pollen grains of *waxy* corn, which, because of their chromosomal composition, show up any mutation immediately. This stain reaction accordingly affords a convenient test for the detection of increased mutation rates.

The test is run in the following manner. *Waxy* corn plants are grown in a field without herbicides, and the tassels are collected at flowering time and preserved in a 70 percent ethyl alcohol solution until analysis. At that stage, the pollen grains are removed from the tassels and placed on a microscope slide. The iodine-potassium iodide reagent is added, and in most runs, the reagent turns all the pollen grains tan. Occasionally, however, a pollen grain will stain a deep blue, indicating a mutation from the *waxy* gene back to standard corn. Such a change is produced, it is assumed, by a random mutational event, possibly initiated by a cosmic ray or chemical mutagen in the environment. Whatever the cause, these occasional spontaneous back mutations in the *waxy* gene are found to occur only once in about 100,000 pollen grains. But in plants exposed to as little as 10 parts per million of the atrazine herbicide in the soil, the mutation rate of *waxy* genes is increased to about 25 to 30 occurrences per 100,000 grains. Thus, it appears that atrazine exerts a mutagenic effect on corn pollen when the plant is grown in soil containing even traces of the chemical.

Experimentalists had previously applied atrazine to similarly "labeled" microorganisms, containing genes whose mutation could be easily diagnosed by simple color or growth reactions. Although some researchers obtained positive results, the great bulk of the evidence was negative, and it was on that basis that atrazine had been given its clean bill of health.

Struck by their strongly positive results on corn, Plewa and Gentile decided to isolate the active material in the atrazine metabolic product for further testing. They ground up the leaves and kernels of their atrazine-treated plants in water, centrifuged away the debris, and kept the remaining fluid. To preserve the extract, they freeze-dried it under high vacuum to a powder. Small samples of the leaf and kernel powder could then be applied in appropriate solutions to the usual microbial test organisms. These include certain yeasts that have found wide use in the diagnosis of mutations and a bacterium that has recently been used to detect mutagenic chemicals in some cosmetics and hair treatment preparations.

In one yeast assay, a mutant—which had originally been produced by a known mutagen—was caused by the unknown atrazine metabolite to back mutate to the standard form. It appeared that the yeast DNA had been converted back to the normal form. Neither pure atrazine itself nor extracts of corn not treated with atrazine produced these effects; the mutagenic activity was thus clearly the result of an interaction between the plant and the herbicide. Similar, al-

though less striking, data were obtained when the same tests were run on two other herbicidal compounds that are related to each other but not to atrazine. These results point to the desirability, even the necessity, of proceeding with equivalent investigations on still other major herbicidal chemicals.

Plewa and Gentile have continued their analysis of the active material in the atrazine metabolite. On thin layers of silica gel, the components of the corn plant extract can be separated so as to yield at least two active mutagens that work on test yeasts and the above-mentioned bacterium. These mutagens are water soluble and probably act by causing a base-pair substitution in the DNA chain making up the hereditary material of the test organisms. The resemblance between atrazine and the four bases that normally make up DNA had previously been noted by other investigators. Even more suggestive in this connection are other herbicides built of substances that are actually modifications of one of the DNA bases. Subjected to the Plewa-Gentile type of analysis, and in light of the experience with atrazine, these herbicides might also be expected to show mutational activity.

This work does not, of course, prove that atrazine-treated corn causes mutations in humans. For one thing, the active metabolic product might be broken down by the acidic conditions of the human stomach or might never be absorbed from the gastrointestinal tract into body tissue. Even if the active material were to enter the body, it might readily be detoxified by the liver or some other body decontamination center. It is also possible that, despite its effect on corn and microorganisms, the substance might not act on humans or animals at all. That, however, would be unexpected, since DNA is similar in all living organisms, and what affects the DNA of one creature should affect that of all.

It appears likely that we will see a marked extension of the kind of testing initiated by Plewa and Gentile. The results may put pressure on the Environmental Protection Agency, the Food and Drug Administration, and the National Institutes of Health to take a position on the continued use of atrazine and related compounds. In the meantime, the organic farming aficionados, who grow only products produced without herbicides or pesticides, would appear to be taking the most prudent course, at least from the point of view of public health.

While no sensible person would claim that we should stop using all chemical compounds in agriculture, mounting evidence indicates that we have not been sufficiently careful in screening these agents before their widespread production and extensive use. Through the serious participation of industry and government, as well as the technical and environmental sciences, it should be possible to find a balanced approach in developing new testing criteria and a better answer to "how safe should safe be?" More stringent criteria may well lead to screening programs that are more complicated, more expensive, and longer than those now in practice. Under these circumstances, alternatives to the use of herbicides and pesticides may become more feasible in terms of economics as well as public health.

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Politicking in Ancient Persia

by Bernard Goldman

Do the walls of Persepolis hold the evidence of a 2,500-year-old "cover-up"?

The palace ruins of the ancient Persian kings in southwestern Iran become more popular every year as a tourist attraction. They are reached in an hour's drive on the main highway from Shiraz to Isfahan, across the broad plain of Marv Dasht to the foot of the Kuh-i Ramat—the "Mountain of Mercy." Poppy fields, the colorful tent city erected for the 2,500-year celebration of the monarchy, and a luxurious new hotel greet the visitor before he reaches the high, stone-walled terrace nestled against the Kuh-i Ramat. A modest entrance fee permits one to climb up a broad double staircase to the top of the terrace, in places more than forty feet above the plain, where stand—in various stages of preservation—the remains of a seemingly endless complex of palaces, audience halls, gates, and apartments tapestried with relief sculpture.

Although the ruins were never completely concealed, scientific excavation was not undertaken until the 1930s when the Oriental Institute of the University of Chicago mounted yearly archeological campaigns. In the 1940s the Iranian government took over the work, which it still continues with the assistance of an Italian commission that is carefully restoring some of the shattered remains. The site, called Persepolis by the Greeks, was one of several palatial administrative centers (others were at Susa, Babylon, and Ecbatana, or modern Hamadan) that held the well-oiled machinery necessary to run one of the great bureaucracies of the ancient world, the Persian dynasty of the Achaemenids. Their empire covered almost all of the Near East and Asia Minor, as well as Egypt and parts of southeastern Europe.

Building at Persepolis was begun by Darius I shortly after 522 B.C. He probably called the place Parsa, which is related to the name *Persian*, as well as to the name of the modern province of that region, Fars, and the present Persian language, Farsi (in which the letters *p* and *f* are related and often interchangeable). Locally today the site is called Takht-i Jamshid, the "throne" of the legendary hero Jamshid. The hundreds of feet of relief sculpture on the buildings, or more accurately, chiefly on the platforms that are the substructures for several of the buildings, beggar description. It is as if a bustling royal court of 2,500 years ago had suddenly been petrified, transformed into stone by one of the fabulous Eastern jinn and thus preserved for eternity. Ordinarily we would not bother to ask why a king would lavish such care in the decoration of his palaces because the answer seems too obvious: princely self-aggrandizement, royal display of affluence and power, love of luxury, ego indulgence, and last but hardly least, cultural delight and esthetic pleasure in the beautiful. For, although separated by thousands of miles and many centuries, the Achaemenids, in surrounding themselves with art, were little different from the Bourbons, the Hapsburgs, the Medicis, or the Romanovs. But is that answer sufficient? The lavish sculpture of Persepolis may be more than an expression of royal sentiment and cultural preference; it may also reveal a hard-headed policy decision, an astute public relations program to sell to the folk of the empire the most important commodity a kingdom has to offer—the king himself!

Darius I, like Caesar, Napoleon, or von Bismarck, was neither born nor raised as heir apparent. Like Alexander the Great, Caesar Augustus, and Genghis Khan, he fought his way to the throne room over the bodies of those who opposed his right to rule. These men who wore the purple by virtue of the sword, rather than by the legality of inheritance, often mounted propaganda campaigns to legitimatize their rule, to convince the people that they reigned by a right at least as great as that of lineage. Such use of a higher justification for taking power no doubt goes back to the beginnings of the natural history of politics. Darius, having seized power, bent his best efforts to convince all men that only he could preserve the state from anarchy and misrule, that only he was the chosen of god and history to direct the destiny of empire.

Darius and his son Xerxes are best known to the Western world, not for their long years of successful rule in Asia, but rather for their failures when they tried to invade Greece. Our informants on the Persian invasions are Greek writers. They describe the battles: Greek heroism pitted against Persian cunning at Thermopylae, on the plain of Marathon, and in the bay of Salamis. Because of these Greek sources we know the Persian kings by Greek names, Darius and Xerxes, rather than by their proper Persian titles,

Darius I, portrayed in stone as a hero, is locked in mortal combat with an imaginary beast.

Bernard Goldman and George Booth

Bernard Goldman and George Booth

The tomb of Darius is cut into a sheer cliff wall. On a relief above the doorway, the hero-king is held aloft on a stool by the people of his realm. At left, a row of Persian guards lines a wide stairway that led to the palace.

Darayavaush and Khshayarsha. But the military disasters in Greece came long after Darius had fought his way to the throne and then ordered his higher justification carved under his self-portrait on the cliff wall at Bisitun near modern Kermanshah. Copies of this official proclamation were sent by the king to the far corners of his empire.

In his "inaugural" statement Darius first establishes his bloodline five generations back, to the founder of the dynasty, thus making his first point: although from a collateral line, royal blood runs in his veins. His second claim is made by fiat: Ahura Mazda, god of the Persians, gave him the kingdom to rule. Yet, this is not more than any king might claim on ascending the throne. But Darius goes on to another matter, a political inconvenience that gives to his claim here at Bisitun, and to the sculptural display at Persepolis, an unusual poignancy and purpose. Another man had already laid claim to the throne on far stronger grounds! Whether this man was whom he claimed to be, we shall never know, even though on his identification depends the reputation of Darius as either hero of the nation or as regicide.

The man claimed to be the son of Cyrus the Great, the most noble and beloved of Persian kings, and the younger brother of the (then) king, Cambyses. Not true, says Darius: the real younger brother was long dead, slain by order of Cambyses who kept his fratricide secret. But a Magus (a member of the clan specializing in cult functions) from the Median side of the empire, who bore a resemblance to the murdered prince, pretended to be him, fomented revolt, and claimed the throne as his father's heir. Meanwhile, Cambyses died, possibly of accidental blood poisoning or perhaps by his own hand, throwing the realm into political chaos. Fear swept the land Darius reports, for the false king slaughtered the opposition, appropriated herds and fields, and funneled the riches of the people into his own coffers. Thus it fell to Darius as a sacred trust to restore tranquility and reestablish the dynasty. He asked the help of Ahura Mazda; it was given, and the imposter fell to Darius's sword. A year of hard fighting cleaned out the remaining pockets of rebellion. Darius brought the ship of state safely off the shoals of anarchy, returned to the people that which was rightfully theirs, and proclaimed a new deal of truth, respect, and justice for all.

A curious tale it is—of concealed murder, mysterious death, coincidental resemblance. But that is the only story we have, the justification written by Darius and repeated in a somewhat elaborated form by the Greek storyteller and historian Herodotus. Perhaps we would be less suspicious if Darius had not protested so much, insisting on the importance of truth, the evil of lying. The scholarly debate continues over whether his proclamation at Bisitun is the true political record or a part of the Big Lie, a 2,500-year-old Watergate.

Although we cannot know the truth of the story, the suspicion that Darius came to the crown against the will of many and, therefore, had to mend political fences and win over skeptical citizens haunts the ancient tale. In this light the inscriptions at Bisitun demonstrate the direct approach. At Persepolis he utilized a more subtle and far more profound technique than the written word (after all, few could read the cuneiform, but everyone could read pictures). Through the medium of pictorial reliefs, Darius launched his higher justification out of the documentary-historical into the cosmic realm of the folk epic, with himself cast as the mythic hero.

The careers of heroes, real and imaginary, generally follow a fairly standard pattern. The hero's birth is marked by unnatural events or occurs in a wondrous fashion. As a child he goes through a period of concealment or anonymity, but at the crucial moment in his people's history he appears and performs the feat that is beyond the capacity of everyone else. Then he is recognized as the benefac-

Bruno Barbey, Magnum

Bernard Goldman and George Booth

Officials of the Persian realm, dressed in long tunics and high, fluted hats, chat informally as they wait to present themselves to the king.

tor of the nation, elevated above all men, and finally, accorded the hero's reward—homage and precious gifts. The climactic act (and that is where Darius picks up the story at Persepolis) of the hero often is in the realm of the fantastic: Gilgamesh, Sampson, David, Theseus, Heracles, Jason, Perseus, Beowolf, Siegfried, Krishna, each stands alone to defeat a fabulous monster, dragon, troll, lion, minotaur, gorgon, serpent. This combat not only stamps the hero as superhuman but also as the chosen of the gods. A visit through the streets and corridors of Persepolis illustrates Darius's use of the pattern.

Only the stone doorjambs and lintels and the window frames still stand above the foundations of Darius's personal palace. As we enter through these doors we see Darius carved in stone, greater than life, locked in mortal combat with real and imaginary beasts. He stands calmly, grasping a monster with one hand while the other deals the death blow. All is accomplished with stately dignity, for there is no question as to the outcome: the hero has been foreordained the victor and both parties know it. Hence, rather than illustrating a savage contest, a sacrament of death is performed. We are not told the name of the beast or what he represents. He may symbolize the enemies of the state or represent the chaos from which Darius saved the empire; he may be the totemic symbol of the royal clan or personify evil, the forces of darkness, or falsehood. Yet his identification is of minor value because the monster is of less significance than is its importance in providing Darius with the necessary opposition to prove his manifest destiny as sovereign and savior.

The palaces of Persepolis were the stage for the tribute nations' celebration of the New Year at the spring solstice. It was the time for the renewal of the oath of fealty to the liege lord. We can retrace with little difficulty the once glittering avenues that lead from the small palace of Darius to a square-columned hall, whose doorways are once again decorated with portraits of the king, but now depicted in the subsequent stage of the hero's progress. Now the king sits upon a throne, his feet upon a footstool, the usual symbol of high rank. It would be misleading to regard this carving as simply a formal, court portrait. As in the portrayal of Darius slaying the monsters, here a mythical idea is cloaked in real-life trappings. King and throne are mounted upon a gigantic stool lifted a few inches off the ground by rows of men, each dressed in the peculiar costume of the foreign tributary land he represents. Hair and beard styles, as well as facial characteristics, are carefully detailed by the sculptors to distinguish one ethnic type from the next. The picture is quite clear in its implied meaning: the hero-king is now recognized as such by the peoples of all nations, who raise him above other men. Probably a similar scene was actually performed in antiquity when the enthroned king was borne out of his palace in his sella or cathedra on the shoulders of the delegates to be acclaimed by the multitude. Beauty queens and football coaches keep the tradition alive today.

The third and last stage of the hero's progress from obscurity to renown is portrayed on the most extensive double set of reliefs at Persepolis. They are carved on the stone revetments, stairways, and balustrades of the raised platform for a huge audience hall begun by Darius and completed by Xerxes. The building itself has almost disappeared; only a handful of tall stone columns, which once supported the beamed wooden roof, still stand outlined against the sky. The exterior walls, originally several feet thick, were made of adobe brick, just as they are made in Iranian villages today. These brick walls are durable as long as there is a protecting roof, but once that is gone, the clay molders. But the stone slabs covering the supporting platform were protected by the accumulating debris until the spade of the archeologist brought them to light. The east and the north revetments carry the sculpture. The eastern wall, however, had collapsed in antiquity, perhaps when the palace was destroyed in 330 B.C., and was soon covered. A large part of the north revetment remained standing and, hence, was exposed to the weather and, worse, to human destruction. Souvenir hunters and traders chipped and sawed out sections of the carved

Persian (left) and Median (right) household attendants bring provisions for the elaborate New Year's banquet of the royal court.

Boucas, Rapho-Guillemette/Photo Researchers

stone, which are now displayed in museums around the world. Over the years the natives of the region, following the injunction against graven images that Islam adopted from the Old Testament, gouged out the faces or the eyes of the figures.

The two walls, east and north, show two views of the same scene: row upon row of parading men—Persians, Medes, Babylonians, Egyptians, East Greeks, Indians, Armenians, Assyrians, Scythians—the imperial guard and delegates from the farthest corners of the empire. Each national delegation of four to eight men is solemnly led into the royal presence by a Persian or Median usher. The envoys carry their tokens, the gifts that acknowledge the overlordship of the king—precious perfumes and unguents in fluted jars and bottles, delicately worked jewelry, golden daggers, tailored linens, and raw furs. Some bring heavy-fleeced, broad-tailed sheep, stallions from the alpine pastures, Bactrian camels, draught oxen, even an okapi. The ranks of delegates walk toward the center of the platform, while from the opposite end parade the household guards. These are the "immortals," so called because none seemed to die in battle (a liberal and immediate practice of substitution for a fallen man kept their ranks unbroken and, hence, counterfeited immortality). In the center of this magnificent façade of envoys and guards was a relief of

Bruce Davidson/Magnum

the king (now removed from its original position) enthroned under an embroidered canopy, receiving the homage of all nations particularized in the person of the grand vizier, who bows before his lord. So sacred is the person of the king that not even the breath of this nobleman may touch him: the vizier holds his hand before his mouth to avert the possibility of contamination.

Thus the hero-king of the Persian world has himself portrayed in the culminating act of political acceptance. If the visitor needed any further convincing that Darius reigned as the proper and chosen master, the spectacle of a never-ending procession of delegates should settle the matter.

The carvings on the other buildings serve to reinforce the message. Waiters, butlers, cooks, and bakers, laden with food and drink for the host, are shown running up and down the stairs. This festive atmosphere of celebration is petrified today in the

The great eastern staircase at Persepolis is adorned with carved reliefs of Persian and Median royal guards (center) and row upon row of imperial houseguards in the rear.

hot sun, along the dusty walks and wasted corridors. We must, in our mind's eye, add the original color—the gilding and painting on the sculpture; the tapestries, drapes, and awnings that provided cool shadows where the functionaries, while celebrating Darius, also passed the day's gossip. The reliefs on the buildings are a marvelous rendering of these elegant bureaucrats: stroking their oiled beards, sniffing the fragrance of a lotus, tapping a neighbor's shoulder to make a point, or grasping the hand of a confidant while deep in court intrigue. These intimate details of court life 2,500 years ago are ample compensation for whatever political machinations they may have served.

Was the dream of Darius to be recognized as the hero of the people a success? It would appear so. His line continued until the empire was shattered by a foreigner. We would not be far wrong in guessing that Darius, like the head of any dynasty—political or commercial—would not be satisfied with contemporary success only. Generations to come must believe in him; his name must remain a legend after the mortal man has gone. But we must not lay too much at the door of personal pride, for in doing so we would underestimate Darius's political common sense. There were sons and grandsons to succeed him after his death; their right to rule depended in large measure upon history continuing to regard him, even after his death, as the rightful ruler.

Thus, we have one of the motivations for the elaborate rock-cut tomb just a few kilometers north of Persepolis. A sheer cliff wall, known today by the name Naqsh-i Rustam ("portrait of Rustam," a later Persian hero), contains a row of four royal tombs. That of Darius (copied in shape and decoration by his followers) is cut in the form of a Greek cross. The center is carved to resemble a columned portico; the doorway leads into a chamber with troughs cut into the floor to receive the coffins. Above the tomb chamber is carved a portrait of the hero who ruled the walls of Persepolis. Now Darius stands on a monumental stool that is once again lifted on the raised arms of the tribute nations. He salutes before an altar of fire the floating figure of Ahura Mazda, who acknowledges the salutation with raised hand.

At Naqsh-i Rustam, the fairy tale story of the man who saved his land from the tyranny of a wicked imposter ends. The palace and grave carvings speak of a shrewd estimate of human nature, of mass psychology. They were part of a policy hatched in the innermost circle of the court. But just as some of the noblest works of mankind have had their germ in the meanest of reasons, so the sculpture is among the most beautiful we have received from antiquity.

When the royal line of the Achaemenid dynasty was broken, it was not due to the insufficiency of Darius's planning. Rather, a new hero had entered Near Eastern history. Like Darius, he had great ambition, he was invincible, and he assumed he was peculiarly chosen. In 330 B.C., Alexander the Great defeated the last of the Persian kings, Darius III, took Persepolis, and by accident or design, destroyed it by fire.

It is an interesting footnote to the history of Persia that Alexander's propaganda machine was, if anything, even more imaginative than that of Darius and equally effective. Alexander took the Macedonian throne after his father, Philip, died on an assassin's blade. We do not know if that sword was hired by foreign or Persian money, by Macedonian political enemies, or by the discarded wife of the king, the mother of Alexander. But Alexander quickly took on the dimensions of the hero. The story spread that Alexander's "real" father was no less a hero than Hercules, and the young king did nothing to scotch the story when he had his portraits decorated with the lion skin of Hercules. In Egypt it was rumored that he was the son of the Egyptian god Ammon; hence his coinage shows him wearing that god's ram's horn. Thus, kings and emperors, presidents and prime ministers may change, but political maneuvers remain constant in the natural history of nations. □

King Darius is accompanied by his attendants, one of whom holds a fly whisk over his head.

Bruce Davidson, Magnum

A crèche, or nursery, of young royal terns paddles furiously away from shore to avoid a disturbance. They will return to their island colony when the threat has passed.

Late-blooming Terns

A nursery, and delayed maturity, get a royal tern off to a slow, but successful, start in life

Should you happen upon one of the isolated barrier beach or dredge spoil islands along the Gulf and southeastern Atlantic coasts harboring an active royal tern colony, you would, depending on the time of your visit, be struck either by the simple nests, each with only a single egg, packed together so densely that the incubating birds seem to be touching one another; or by the presence of two different species, royal and sandwich terns, intermingled and tolerant of

Text and photographs by Paul A. Buckley and Francine G. Buckley

each other; or by the hundreds, perhaps thousands, of highly visible, varied, and multicolored chicks, almost no two alike, milling about in a seething amoeboid mass. Each of these phenomena has evolved in response to very special selective forces.

The royal tern is one of the crested terns, a cosmopolitan, essentially pantropical group of seven species that look generally alike. Almost all have long, slender, unmarked yellow or orange bills; silver-gray upperparts (including wings); snow-white underparts; and a prominent black crest, which is sleeked back when the birds are calm but erected menacingly when they are alarmed. North America has three species of crested terns: the royal, *Sterna maxima;* the elegant, *S. elegans,* and the sandwich, *S. sandvicensis*. On this continent, the elegant is restricted as a breeder largely to Baja California. Royal and sandwich terns have essentially concordant breeding ranges on the barrier and offshore islands of the Gulf coast and along the Atlantic coast as far north as the Delmarva Peninsula. (It was on Fisherman's Island National Wildlife Refuge in Virginia and at Cape Hatteras National Seashore that we studied the breeding ecology and behavior of royal terns.) In winter both royal and sandwich terns regularly reach the Caribbean and Pacific coasts of South America, as well as the West Indies and Florida.

Belonging to the Laridae, the family of gulls and terns that has seen so much study, particularly by Niko Tinbergen and his associates at Oxford University, the crested terns have nonetheless been almost ignored by scientists, except for some studies of the European race of sandwich tern. This is not surprising since most members of the group are not freshwater or inland birds, and occur in remote, usually inaccessible coastal locations when breeding.

Typically, royal terns can be found nesting on low, sandy islands throughout their range. New spoil banks, such as those dredged up by the U.S. Army Corps of Engineers, are favored colony sites, usually offering all nesting prerequisites: complete absence of quadruped predators, extensive visibility of surroundings, and broad areas of shallow waters located at or near an inlet connecting ocean with sound or bay—the source of vast quantities of fish with each tidal change. Other characteristics are important but these seem to be the *sine qua nons* for colony establishment.

Colonies successful for decades may suddenly shift for no apparent reason to an adjacent and seemingly identical site, often returning in subsequent years to their original locations. We suspect human disturbance is the most frequent cause for such moves: egging is still practiced in the more isolated locations in the middle and south Atlantic states, and errant fishermen and picnickers can unwittingly cause a colony to move overnight.

Other conditions can force royal terns to move to another nearby location where they will re-lay their eggs. In fact, they seem able to repeatedly re-lay their single-egg clutch; one year a small colony of about 500 pairs on Fisherman's Island re-layed some five times in seven days when flooded out by high tides. The predilection of royal terns for sites offering exceptional lateral visibility for predator detection usually results in their breeding in low places, exposing them to storms and spring tidal flooding. Under such conditions the ability to re-lay rapidly would be highly adaptive.

After royals arrive at their colony area, a month or so is spent courting before a pair actually begins nest site selection. While watching courting royals we became aware of two unusual behaviors associated with the courtship feeding typical of terns, which usually involves the male's catching of a fish and offering it to his prospective mate. (Recent work suggests that females may gauge a male's ability to provide for offspring by his success in this food-offering ritual.)

We noticed that the royals were using very small instars of blue crabs, or "peeler crabs"—the delicious soft-shelled crabs of seafood lovers—as well as fish. Abundant off Virginia and North Carolina at the times the terns were courting, the floating crabs were easily picked up by diving terns. But we observed that terns with crabs in their bills were constantly trying to shift the prey around while in flight,

Packed together as tightly as possible, nesting royal terns thereby reduce their individual vulnerability by presenting the smallest possible perimeter.

resulting in an aerial shuffle we soon came to associate with the transport of a still-struggling crab.

We also noticed a high incidence of royals skimming the water with their bills in the same manner as the highly specialized black skimmer with its elongated lower mandible. We even saw three royals catch fish while water skimming. We first explained this skimming as merely the drinking of salt water (which many seabirds do, some obligatorily), but the more we watched royals that had just caught prey, the more convinced we became of an association between prey catching, especially of crabs, and water skimming.

The claws of crabs that were simply picked up from the water surface may have irritated the terns' bills, and the terns were presumably relieving the irritation by skimming their bills through water. Thus, almost by accident, we gained some insight into the probable origins of water skimming as a feeding method by the now-specialized three species of skimmers that occur in Africa, India, and the Western Hemisphere.

Once a nest site is selected, royal females lay a single egg in small depressions in exposed sand, sometimes lining them with bits of wrack, shells, or fishbones. The nests are not camouflaged, and the eggs are not particularly cryptically colored. Most surprisingly, the adults defecate directly on the nest rims, giving the colony a distinctively whitewashed look

To be fed, a chick must answer its parent's call, emerge from the crèche, and be recognized. As the chick becomes older and bolder, it will attempt to steal food from any nearby adult.

Isolated, low sandy islands off the Gulf and southeastern Atlantic coasts of the United States are favored colony sites. Broad areas of adjacent shallow waters, which contain an abundance of fish, are also necessary for the establishment of a royal tern colony.

(and a pronounced odor). This behavior is exceedingly unusual in gulls and terns, and its absence has been demonstrated to have a high antipredator value, since mammals, particularly, zero in on the smell of feces. The royals, however, nest on quadruped-free islands, so that source of selective pressure is absent. In one colony, a particularly high tide obliterated nearby common tern and black skimmer nests at the same ground level, but the feces-covered, hardened rims of the royal tern nests withstood the scouring floodwaters, eroding away on the sides but not collapsing; the incubating royal tern adults that rode out the storm lost virtually no eggs. Thus there would be a positive selective value for defecation directly on nest rims.

Besides whitewashing, other immediately unusual features of royal tern nests are their size and extreme density per unit area. Colonies of 10,000 pairs are frequent. In our study, we found a mean density of 7.5 nests per square meter. Then in the course of making inter-nest measurements, we noticed a high incidence of single nests surrounded by six other nests, with each adjacent nest sharing all or most of a common rim. We also found a high incidence of single nests with five shared rims, and quite a few with seven; we found no nests sharing more than eight or less than four common rims. Investigation into the scattered, piecemeal literature on the subject of packing of objects in nature disclosed that if objects are pushed to maximal density per unit area in a single plane, as in the case of honeybee hive cells, they tend to assume a six-sided configuration; this condition is called hexagonal packing.

We were able to confirm that there are small areas in royal tern colonies where almost perfect hexagonal packing obtains, but that minor topographical features and probably individual aggression levels preclude perfect regularity. Our data also indicated that, given the limitations of their physical environment, royal terns pack their nests—their only defended territories—as closely together as they can. They maintain their nest scoops by reaching out and lunging at neighbors on all sides.

Why such a high density? Most ornithologists feel that colonial birds, especially ground nesters, show increased density as each bird attempts to get as close as possible to a neighbor to, in effect, hide itself from predators. On a colonial basis, the perimeter, most easily accessible to predators, is smallest when nests are hexagonally packed. Egg-preying laughing gulls are a constant threat to royal terns, but the terns show little threat or other aggressive behavior toward them even when the gulls are caught in the act. Nest packing may thus be the royals' only defense against egg predation, and coupled with their remarkable ability to relay, does seem to be successful.

But there is still heavy pressure from the gulls, whose behavior when

egg preying is extraordinary to behold. Pairs of gulls will often work over unguarded nests on the edge of a royal tern colony, punching neat holes in each egg. If another unguarded nest is nearby, rather than eat the first punctured egg, they usually go over to the next egg and puncture it too. They put this tactic to good advantage if the terns are disturbed and fly up: the gulls, being bolder, are the last to fly when the terns go up, often merely looking upward during the disturbance or, if taking flight, landing before the terns. In a most economical manner, they run around punching single holes in as many tern eggs as they can before their owners return, for a royal tern will not incubate a punctured egg. The gulls can then consume the eggs at their leisure. Severe egg predation by the gulls is made easier by human disturbance of the colonies and may be one of the major causes of the terns' failure to nest successfully in certain localities.

Egg variation in a royal tern colony is strikingly extreme; some eggs are almost white, others are of varying shades up to dark beige; superimposed on all are spots, stripes, and squiggles in bewildering variety. Other than by chance placement, eggs are not cryptically colored. We noticed that returning adults flew over the colony until they had located what seemed the correct general area, then landed, and, peering intently at egg after egg, wandered about until finally settling on one. We believed that adults were using the extreme variation in the eggs as a means of recognizing their own, but that they first located their own part of the colony and then their own egg. Tests that we conducted confirmed this hypothesis, and also indicated to us that

the nest itself plays an important, albeit secondary, role in egg location. We suspect that minor ground differences and probably voice or plumage features of neighbors are the relevant cues. At any rate, the adaptive value in being able to recognize one's own egg under conditions of such extreme nest density is clear, and the relationship between individual egg recognition and a one-egg clutch would seem to be strong. Most other larids have larger clutches, and they recognize their nest sites rather than their eggs.

Incubation in most gulls and terns takes from 21 to 24 days, but in royals it lasts about a month. The single egg is rather large for the size of the adult. Relative data on newly hatched chick weights as a function of adult weights are scarce for most terns, but we suggest that royal terns have concentrated their reproductive resources on producing one well-developed, extremely precocious chick that can immediately run about and swim strongly in the event of floodwaters. At the age of two or three days, it leaves its nest to join the vast nursery, or crèche, that roams over the colony area while the adults are off foraging.

Chicks exhibit a bewildering variety of color combinations; there are almost no two alike. This color variability has often been called polymorphic, but that term is erroneous since true morphs exhibit discrete variability, the color classes being clearly separable from one another. Early in our studies we selected some 400 chicks for careful quantification of color variation. We found that the color of the unfeathered parts (bill, feet, and legs) varied enormously (except that eyes were always black), with practically no correlation between colors of the various body parts. Down color, whether white or light, medium, or dark beige, was uniform over the entire body, but all chicks had white bellies. Superimposed on the down was dark brown spotting, which varied in intensity over different areas of the body. There was a correlation between extent of spotting and the presence of a dusky bill tip, suggesting common pigmentation. We concluded that probably four polygenic pigmentation systems were responsible for, respectively, bill color, leg color, down color, and extent of spotting—the areas where variation was great.

Since there was a tendency for light-colored birds to be more numerous than dark birds, thermoregulatory considerations might play a role in the distribution of color combinations and over-all pigmentation. The temperature often approaches 150°F on the open, hot sand where a chick is left unprotected by its parents, and on occasion chicks die from the heat. Lighter colored chicks, however, may reflect more sunlight, thereby remaining cooler.

We also believe that since cryptic coloration was not being selected for or conspicuous colors being selected against, inherent down plumage variability could be expressed. This extraordinary color variability—among the greatest known for a single species of bird—might itself assume increased positive selective value if color difference could be used by returning adults to identify their own young in the crèche.

The behavioral sequence typically seen when an adult returned to the crèche with a fish gave us some clues to adult–young recognition. An adult would fly over the crèche area giving the "keer-eet" call. Upon hearing an answering chick, the adult would immediately land in the general section of the crèche where the chick had called. The adult would call again, the chick would respond, and this antiphonal calling would continue until the chick had worked its way through the crèche to the adult. At that point the adult would peer intently at the chick, each would call again, and, presumably, the correct information having been exchanged, the chick would be fed. On several occasions we saw the entire sequence followed without incident right up to the time the chick emerged from the crèche, called to the adult, was answered, and lunged for the fish, only to be rewarded with a whack on the head as the adult rushed off. It appeared that while the chick sounded right, it didn't look right; hence, no food.

Such behavior on the part of the chicks is not surprising since they will, especially when older, try to steal food from any adult, on occasion even jumping up in a usually vain attempt to grab food from the bills of low-flying adults. The adults, therefore, are exceedingly cautious; we have never seen an adult voluntarily feeding what we believed was an alien chick. The precise nature of parents' egg and nest site recognition argues that natural selection would not likely favor indiscriminate, or altruistic, feeding behavior. We suspect that the reported instances of promiscuous feeding of chicks by adults of other crèche-forming birds (penguins, flamingos, some ducks) may be erroneous or only of accidental occurrence.

The phenomenon of the crèche is possibly the most striking aspect of a royal tern colony. The term comes directly from the French word for "nursery," and one more apt is not

Adults are efficient foragers. Young birds do not attain the fishing success of their elders until they are two years of age or older, one reason for delayed breeding in this species.

available. It is a common nursery to which all chicks belong, leaving their nest scoops at about two to three days of age, never to return. Relaxed, the crèche is a loose flock of young scattered over a reasonably limited area of the colony, away from the nest sites. There seems to be preference to be near some vegetation under which the young birds can escape the searing sun or to be at the water's edge where the airflow over the water surface veers upward at the water–sand interface, giving a slight, cooling breeze.

The crèche location varies each day, and seems to be essentially unprogrammed as the chicks wander over the colony site. A few adults are usually present, less as guards than as parents feeding or otherwise attending their own chicks. A frequent ratio is perhaps ten chicks for every adult at any given moment in midday; the rest of the adults are off foraging.

Once the crèche area is alarmed following invasion by a predator (often biped), it undergoes a rapid transformation: all the chicks surge together into a tight, rapidly moving mass, with attendant adults hovering overhead giving alarm calls. The crèche then moves as a unit, often taking to the water without hesitation, the flotilla paddling furiously away from shore. Once the disturbance is over, the creche relaxes and the adults settle back near the chicks. During a disturbance there is little indication that the adults are in any way directing or controlling the creche.

The great size distribution of chicks in a crèche is almost as impressive as their color variability. Since they remain in the creche from about their third to their thirty-third day of life, at which time they fledge, this is not surprising. Birds ready to fledge are fully as big as adults and may weigh more; three-day-old chicks are tiny. One might imagine their being trampled by the larger birds in a rapidly moving, alarmed crèche, and this does happen. We feel that the chicks' need for relatively larger size and greater strength at hatching than their non-crèche congeners has been an additional selective factor responsible for the extended incubation period and large single egg. Interestingly, over-all mortality in a creche is very low if one compares the number of dead royal tern chicks in an active colony with similar body counts from skimmer or common and least tern colonies.

The answer to the question, Why is there a creche system in royal terns? is complex, and directly tied to the question, Why do royal terns nest so densely? In fact the entire social system of this species has evolved in response to a labyrinth of interconnected environmental pressures. We think several of the more important factors responsible for the occurrence of a creche are: (1) the chick's tendency to wander from the nest site for a number of reasons (it is often left alone by its foraging parents, the sand is very hot, and the chick is often unshielded because its parents are absent; neighboring adults, unlike most other terns, do not react murderously to trespassing alien chicks); (2) the predation that a single wandering chick is subject to favors clustering of chicks in the same manner that their nests are clustered; and (3) the probable need for the parents being able to locate the chick easily and rapidly, feed it, and then be off foraging again. Many other variables may have played a role in crèche evolution.

We have indicated that the adults' aggression is low, and this is true of royals at all stages of their lives. It does reach a peak in adults, though, at precisely that time when the chicks are most vulnerable and need their parents' protection the most: at two to three days of age, when they are leaving the nest to join the crèche.

Chicks are rather docile until in the crèche a few days; then their boldness increases to the point of attempting to rob any passing adult of its fish. Normally chicks show little aggression toward one another. As the young approach fledging and increase in size, a drastic change occurs in their behavior. Instead of lunging at any available fish, proffered or not, they now adopt the hunched attitude typical of virtually all submissive adult larids and give a whinnying call heard at only one other time: when given by an adult female to signify her submission to her mate and readiness for copulation. In both cases a premium is placed on communicating the submissive bird's nonthreatening inten-

tions: the one to be fed, the other to allow copulation.

Once they fledge, the chicks do not remain long in the colony area. Post-breeding dispersal in larids typically spreads the juveniles farther from their natal colonies than at any other time in their lives. Royal terns are not exempt from this rule, but unlike most gulls and terns, the adults accompany their juvenile as far as it may wander, even beyond its expected range. Only a month after fledging, one of our color-marked juveniles, with adults, was seen at Barnegat Inlet, New Jersey, some 200 miles north of its Fisherman's Island colony. And birds from the same colony regularly reach New England by autumn. Southward, dispersal and wintering distances are greater, birds from Fisherman's Island ranging to Florida, most of the West Indies, Central America, and the northern coast of South America.

The late David Lack and his colleagues at Oxford examined certain peculiar aspects of some seabirds' breeding regimes, notably one (or two) egg clutches, extended parental care, and delayed first breeding. They have postulated that, generally speaking, breeding pairs of birds try to raise as many offspring as they can, and that low clutch sizes are *ipso facto* proof of an inability to raise more to maturity. By extension, prolonged parental care—such as is typical of the crested terns—indicates that the juveniles of species practicing it are not sufficiently able to meet their own food-energy requirements. Hard data supportive of Lack's hypothesis are few and far between, and there are indications that the breeding regimes of some tropical land birds may follow another piper. However, comparative studies of young and adult little blue herons, brown pelicans, and sandwich terns have supported the notion of a relative prey-capture inefficiency of sufficient magnitude to postpone the age at first breeding by several years until the would-be parent is able to feed not only itself but also a mate and young.

During 1970 and 1971 we spent about ten days each January on the island of Bonaire in the Netherlands Antilles, a short distance off the Venezuelan coast. About 100 wintering adult and juvenile royals rested and fed at the salt pans along the southwest side of the island, site of the famed Bonaire flamingo colony. We paid particular attention to the relative foraging efficiencies of both young and adult royals and were able to confirm and extend the conclusions of the other studies.

We found significant differences between adults and young in the following foraging parameters: (1) mean time fishing along a given stretch of beach (adults spending only half the time juveniles did); (2) mean number of dives per minute (adults diving almost twice as frequently); (3) initially successful dives per minute (adults about 50 percent more successful); and (4) ultimately successful dives per minute (adults still about 50 percent more successful). The difference between initial and ultimate success was an attempt to see if adults held on to, and ultimately ate, a greater percentage of their catch than juveniles; they did, but only because their initial success rate was higher. Juveniles did not lose any more fish than adults did. Curiously, adults did not make more successful dives than juveniles, but since they dove more frequently, their time-efficiency was higher.

We also found an extremely subtle but important difference between adults and juveniles. Juveniles dropped but then recovered their fish between ten and fifteen times more frequently per bird, per dive, or per minute than adults, even though ultimately they did not lose any more fish than adults did. This took a toll in two ways: (1) the energy expended in diving after a slippery fish, recapturing it, dropping it, and so on was surely inefficient in terms of the energy ultimately obtained when the fish was safely digested; (2) because they were constantly dropping and recapturing fish, the juveniles simply did not have enough time to make as many dives per minute as adults, even though their catch success did not differ from adults.

The juveniles were indeed probably not capable of sustaining themselves, even when they fished most of the time. They frequently followed adults (presumably their parents), begging for food from them. We regularly saw adults catch fish and feed them to their demanding young, but usually only in the afternoon, after the adults had been feeding themselves all morning, and the juveniles had been trying to do likewise.

Banding data seem to indicate that many juveniles spend their first and probably their second summers on their wintering grounds. Their parents might summer with them on occasion, but most adults probably return to their breeding colonies each season. Our data showed less than 5 percent of breeders in Virginia and North Carolina colonies under three years old. Studies on other species of larids indicate that even where delayed first breeding is not especially prevalent, birds breeding for the first time are usually less successful in producing flying offspring than are older, more experienced birds. Most successful of all are members of a pair that have bred with each other before. This success hierarchy would certainly be accentuated if, in addition, the hunting skills of the younger birds were suboptimal—as they are in yearling royals—and would probably be sufficient reason alone to select for delayed maturity. Older first breeders would be able to raise and accompany to the wintering ground their own young, while still feeding themselves. This is probably the case with royal terns.

The social system of royal terns, which evolved in response to complex interactions between behavioral and ecological factors, has enabled the birds to survive over a relatively small breeding range in a narrow coastal-offshore belt, with only a few dense (but potentially vulnerable) colonies. As a mark of their success, royal terns are currently undergoing a northward expansion of their Atlantic coast breeding range. It will be interesting to see if they can cope with man's degradation of coastal habitat should they reach the Middle Atlantic and New England states. □

Aggressive behavior is minimal among royal terns. They often breed in the same area as sandwich terns, never attack alien chicks and, rarely, egg-preying gulls.

Around the Ice Age World

by George J. Kukla

A global tour 18,000 years ago at the peak of the last glacial epoch would reveal many totally unrecognizable landscapes

Recent studies show that the earth has undergone ten major glaciations in the past million years and many more in earlier times. The most recent ice episode began more than 100,000 years ago; reached its height, after several oscillations, about 18,000 years ago; and ended about 10,000 years ago. We are currently in a warm, or interglacial, period.

During the ice ages, huge ice sheets and mountain glaciers, often more than 10,000 feet thick, formed in the northern latitudes. Because so much water was locked up in land-based ice, the sea level fell, exposing previously submerged terrain. Northern regions and high mountains everywhere were covered with ice. For example, Mauna Loa, the 13,680-foot-high active volcano in Hawaii, and Mount Kilimanjaro, the 19,565-foot dormant volcano in Africa, were both glaciated 18,000 years ago. The low latitudes were subjected to extended periods of drought; consequently, deserts expanded and forests shrank.

Region by region, what was the glacial world like 18,000 years ago? For more than a century, scores of geologists, paleontologists, and geochemists have been trying to piece together its image, using such clues as boulders left behind by the glaciers, pollen grains of past vegetation preserved in lake beds, animal bones buried in caves, and ancient soils exposed in pits dug for brick-making material.

No single tooth or leaf or soil pattern can by itself establish the terrain and climate of a given area in a past epoch. But if an assemblage of clues contains the fossil remnants of plants and animals that live today only in regions with a harsh arctic climate—and no remnants of organisms from warmer areas—it must be concluded, even when the fossils are found in temperate zones, that those regions were once much colder. In recent decades, radiometric methods have provided a tool for the accurate dating of the above-mentioned finds. In addition, sophisticated computers have made it possible to reconstruct past sea-surface temperatures from the composition of fossil plankton collected on the ocean bottom.

Thus, a picture of the world at the peak of the last glaciation has begun to emerge. The image is not yet complete—numerous pieces of evidence are either problematical or poorly dated, and information concerning large portions of both the continents and the oceans is still sketchy—but analogue assumptions are used to fill in the gaps.

Using every method available, scientists affiliated with an international consortium known as CLIMAP (for Climate/Long-Range Investigation, Mapping, and Prediction) have recently assembled their first, somewhat spotty reconstruction of the earth's surface, including the land and the oceans, as it was 18,000 years ago. They are now compiling additional data to improve their initial primitive model.

Although much remains uncertain, many interesting features of the 18,000-year-old world are well established. We are sure, for example, that present-day New York City was under a huge ice sheet several hundred yards thick. Gusts of bitterly cold wind chased sand across the bare outwash plain that stretched along the foot of the glacier south of the area. Because the sea level had dropped, the shoreline was many miles to the south.

The ice melted away long ago but we can trace its extent from the deep scars and scratches, still visible today, it made in granite outcrops in the Bronx and along the Palisades on

the western bank of the Hudson River. The glaciers also left behind blocks of alien rocks picked up in the Catskill and Adirondack mountains, hundreds of miles north of the city. In Queens, northern New Jersey, and along the Hudson River, laminated deposits composed alternately of sand and clay are now found. These layers, known as varves, were formed in ice-dammed lakes. Elongated hills, or moraines—deposits of unsorted sand, gravel, and loam left by retreating glaciers—mark former glacier terminals on Long Island. Wood fragments occasionally found in the moraines make it possible to fix the age of the glaciation by radiocarbon dating.

Partially submerged moraines now stretch northeastward toward the Massachusetts islands of Martha's Vineyard and Nantucket, others extend west across the Appalachian Mountains into Pennsylvania and Ohio, and still farther west to Illinois, Iowa, and South Dakota, marking the border of the maximum ice advance. A narrow strip of tundra and steppe bordered the ice margin, and pine and spruce forests extended farther south toward the Gulf of Mexico. The Gulf Coast and the Caribbean Islands were warm and relatively dry in summer but cold and probably rainy in winter. By contrast, the weather around New York City was never pleasant. Vigorous storms dumped snow and rain over the area throughout most of the year. The stormy weather was caused in part by the steep temperature gradient created between the warm ocean and the cold land, which greatly surpassed anything known in recent times.

The effect of glaciation can be seen along the front of the Moreno Glacier in the Andes Mountains on the Chile-Argentine border. The glacier plows up the earth, knocks over trees, and sweeps all before it as it advances.

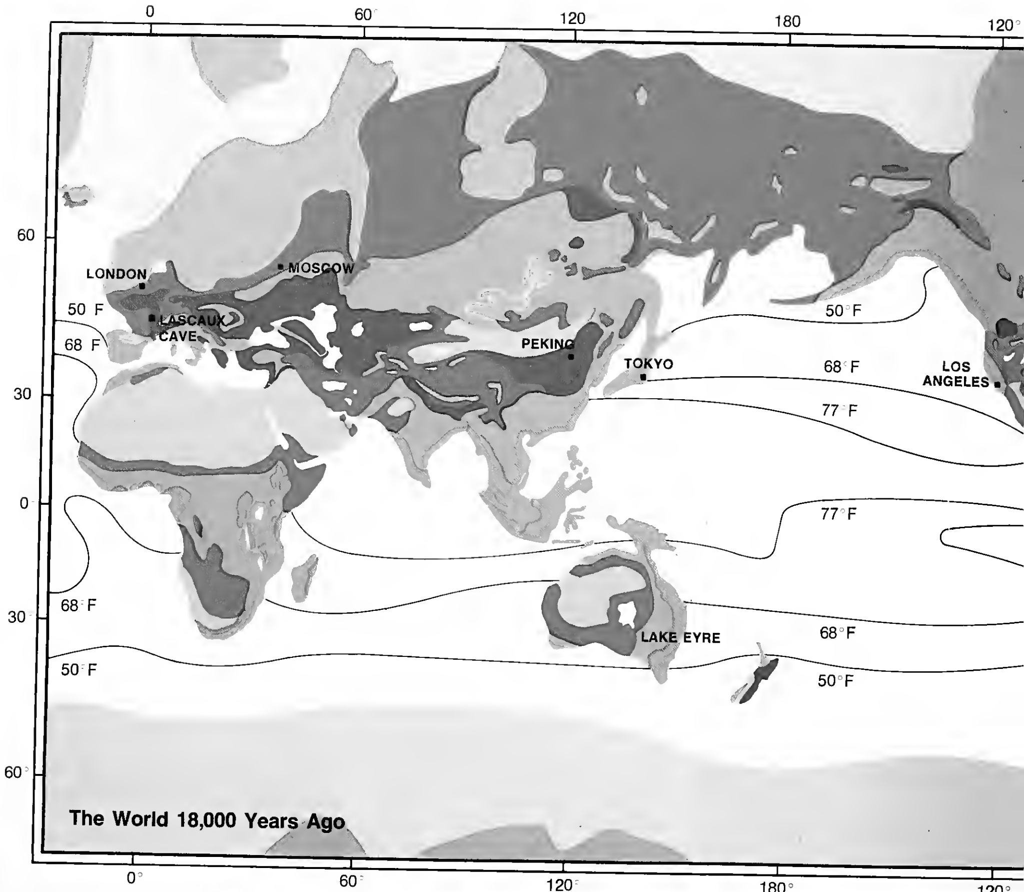
John H. Mercer

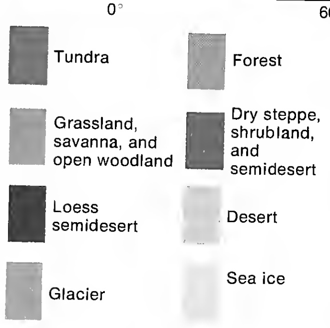
Let us now cross the ocean and look at Europe, stopping first in France. No natural boundary separated France from England 18,000 years ago since the English Channel was then dry. While a good part of England was buried under ice, France escaped glaciation. The country's barren plains were covered with dusty yellowish-brown soil, or loess, and dotted with rare patches of grass. An airborne deposit of dust storms, loess was common during glacial times in the windy mid-latitudes of Europe and Asia. Icy tundra, similar to that found in the Canadian archipelago and Lapland today, stretched northward from the loess belt.

There may have been some warm summer days in east-central France 18,000 years ago. However, the nights were cold and the winters long and rough. Where some of the best wine grapes are grown today, in the Rhone Valley, for example, thick deposits of eboulis—angular inch-sized limestone fragments—testify to the strength of the wind that battered the plains during the last glacial episode. The fragments were unloosed from solid ground by the repeated winter freezing and summer warming of the bare rock and were then picked up by the wind and deposited on the leeward slopes of sheltered valleys. They made a strange kind of air pollution: flying stones with knife-sharp edges.

There was little ice-free land north of the Alps. The front of the continental ice sheet in northern Europe stood close to present-day Hamburg, Berlin, and Warsaw. The piedmont glaciers of the Alps reached the vicinity of Munich and covered Geneva, Zurich, Salzburg, and Innsbruck.

Where ice-free ground did exist, most of it was composed of loess covered sparsely with grass. Snails were the most abundant animals on this

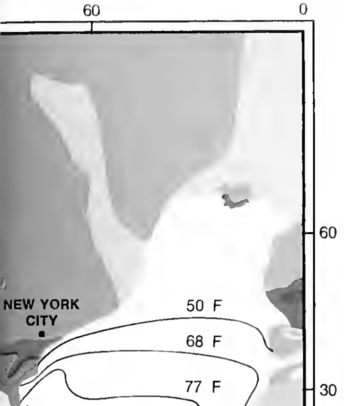




Conditions pertain to summer in the Northern Hemisphere. Maps designed by Clifton Line from information on terrain and sea surface temperature provided by CLIMAP.

barren loess-steppe. Some of the same glacial species can be found today, but only in the high mountains of central Asia, which has bitterly cold weather. This suggests that the climate of central Europe 18,000 years ago was probably similar to that of central Asia today. No vertebrate remains have been reliably dated from the time of the peak glacial epoch, but some indication of what the climate might have been like can be derived from studying the bones buried in loess at Paleolithic sites fifty miles north of Vienna. These locations were occupied by mammoth-hunters about 25,000 years ago, during a relatively mild interval that preceded the glacial maximum. In addition to the bones of mammoths and woolly rhinos, the remains of reindeer, arctic foxes, wolverines, and arctic lemmings have been found. These latter animals could easily live in the contemporary far north of Canada, which implies that the environs of Vienna once resembled today's Canadian Arctic and were probably even colder at the glacial peak.

The landscape and climate of inner Asia and Siberia have remained relatively unchanged. Because of a lack of precipitation, only small glaciers developed in that region. In most of Siberia winters were bitterly cold and probably longer than today, while summers were shorter and cooler, with perhaps an occasional hot day every so often. Although the extent of the permafrost, that is, permanently frozen subsoil, was far greater then, the topsoil melted every sum-



mer, just as it does today. Inland lakes and seas were swollen since evaporation was low during the long winters and cool summers and streams carried in more meltwater from heavily snowed mountains.

At the turn of the century, the carcasses of frozen mammoths, some so well preserved as to be still edible, were found by local hunters in Siberian streamcuts above the Arctic Circle. It was formerly believed that the animals had perished during the peak glacial cold, but it has now been established by radiocarbon dating that most died more than 30,000 years ago, probably during a relatively warm episode. Grass, the food of the mammoths, was then prevalent in the area and was found in the animals' stomachs. They also had their characteristic summer coats of short reddish hair. It is likely that the mammoths pushed north in search of food at the height of the summer season. Whereupon they may well have become inextricably mired in the swampy, melted ground above the permafrost and sunk to their deaths.

Although numerous locations used by Paleolithic hunters have been excavated in Siberia, it is still difficult to reconstruct with accuracy the fauna of the peak glacial interval. Only the fossil remains of such cold-resistant species as reindeer, arctic fox, mammoth, woolly rhino, and wolverine have hitherto been identified from bone heap deposits of the last glacial age. This particular congregation of animals, most of them open-country dwellers, suggests that the Siberian landscape 18,000 years ago was devoid of closed forests. The evidence of open terrain fits well with the wide distribution of wind-blown dust in central Asia, mentioned earlier. Changes of vegetational cover have been reconstructed from studies of pollen grains preserved in lake bottoms and peat bogs, and the past extent of mountain glaciers has been well established from the location of terminal moraines. Only in forested, poorly accessible flatlands does uncertainty remain about how far the ice advanced at the peak of the last glacial episode.

We next turn south, to Venice. The sea has recently threatened to wash away this architectural jewel, but 18,000 years ago, the site was 200 miles inland and a large bay was the only evidence of today's Adriatic. Arctic fox and reindeer were common along the French and Italian Rivieras, and horse herds, ibexes, and wolves roamed through the dry sagebrush steppes in the vicinity of Rome and in the central Apennine Mountains. Only in the valleys of southern Italy would it have been warm enough for mixed pine-oak forests inhabited by stags and donkeys. The Mediterranean Sea, which, unlike the Adriatic, did exist, was a chilly 55°F along the western Italian shore, compared to its present summer temperature of 75°. *Arctica islandica*, a clam commonly found on the Icelandic shelf today, was then abundant along the Italian shore. Information concerning past animal life in Italy comes mainly from cave fills excavated in the search for Paleolithic habitats.

We move next to Australia, a dry and mostly warm country today, whose interior is largely inhospitable desert. Was the country's glacial climate 18,000 years ago more hospitable? By no means. At that time Australia and the islands of New Guinea and Tasmania formed one large continent. Huge sand dunes, like those of the Sahara, covered most of its central and southwestern regions, the product of a severely arid climate and strong winds. The Snowy Mountains in the southeast and the high peaks in the northeast were glaciated. Lake Eyre in southern Australia, which today is a small, salty pond, was an extensive, 200-foot-deep freshwater body, covering 30,000 square miles. Pollen-bearing sediments taken from different parts of the country point to a generally cooler and drier climate and less dense vegetation than now exists. This information may not seem to be in accord with the existence of large lakes such as Eyre, but it has been shown that decreased evaporation due to lower temperatures and greater snowmelt in the headwater areas could have filled the basins even though precipitation during the growing season was low.

What were the southern ocean regions like? The northern edge of the subantarctic pack ice was then in almost the same position in summer that it now occupies in winter. During the Southern Hemisphere's cold season, it expanded some 350 miles toward the equator. Thus, 18,000 years ago there was less seasonal variation in the Antarctic pack ice than there is now, since at present a good part of the ice disappears completely in summer. The former position of the ice boundary was reconstructed from the distribution of radiolarian plankton found in deep-sea cores. The Antarctic continent itself was under ice, much as it is today.

Data from South America and Africa are still very spotty but they do indicate conditions similar to those in other parts of the world: namely, a climate distinctly drier and generally cooler than that of today. Mountain glaciers existed on numerous peaks of equatorial South America, on some peaks of Central America, and along the southern extension of the Andes.

Semidesert composed of dusty loess and sparse grass occupied a good part of northern Argentina. Unexpectedly, deserts with sand dunes were present in the Orinoco basin in Venezuela and along the Amazon River, where today an almost impenetrable tropical rain forest exists.

In similar fashion, the lowland rain forest of the Congo basin in Africa was much smaller 18,000 years ago. This conclusion was reached from studies of the peculiar speciation patterns of lizards and of such birds as parrots and toucans. They indicate the presence of past unforested barrier zones that no longer exist. The deserts of southern Africa, such as Kalahari, extended farther north toward the equator. The flow in the Nile was sluggish and the water level of Lake Chad in north-central Africa and in such east African lakes as Victoria was low.

On the other hand, radiocarbon dating indicates that then existing lakes of western North America, instead of being low, were overflowing with fresh water. Few places in the world today are as desolate, barren, and hot as Death Valley in California. At the peak of the last glacial episode, however, a deep freshwater lake filled much of the existing depression. Water came from melted snow in the neighboring mountain ranges to the west. Other huge inland freshwater seas were Lake Bonneville in Utah and Lake Lahontan in Nevada, whose remainders today are shallow ponds of brine. Pollen studies indicate that the dry vicinities of these former lakes were covered by sparse xerophytic vegetation—plants that can exist with a limited supply of water—not very different from the flora found in the area today.

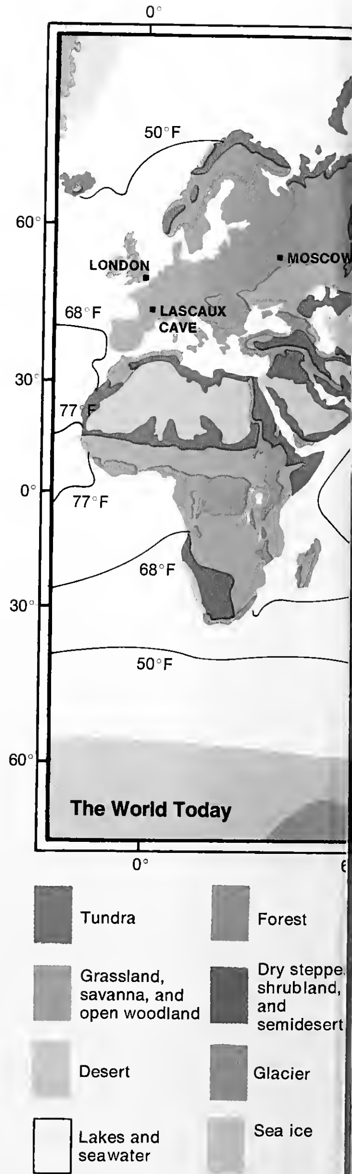
Summarizing our most striking impressions of the glacial world, we would list first the huge continental ice sheets in the mid-latitudes of North America and Europe and extensive glaciations of high mountains all over the world. The North Atlantic was covered with ice and the warm Gulf Stream did not exist. Because of lowered sea levels, continental shelves were exposed and land bridges, such as that connecting Siberia and Alaska, were disclosed. America, Asia, Europe, and Africa formed a single, huge continent. Vegetational cover on land was thinner, a result of generally drier, shorter growing seasons. While deserts mainly expanded, forests shrank. Zones of continental climate, that is, areas displaying large, seasonal temperature differences, expanded; and zones of oceanic climate with relatively little temperature variation between seasons diminished. And, of course, it was colder.

Compared with the present, the greatest temperature differences were in the continents of the Northern Hemisphere, then some twenty degrees colder, and in the low latitude mountains—about ten degrees colder. There was less difference in the surface temperature of the open ocean—an average of four degrees—about a ten-degree difference in the high latitudes, and a negligible temperature variation at about thirty degrees north latitude. Averaged over the entire globe, air surface temperatures may have been lower by about ten degrees.

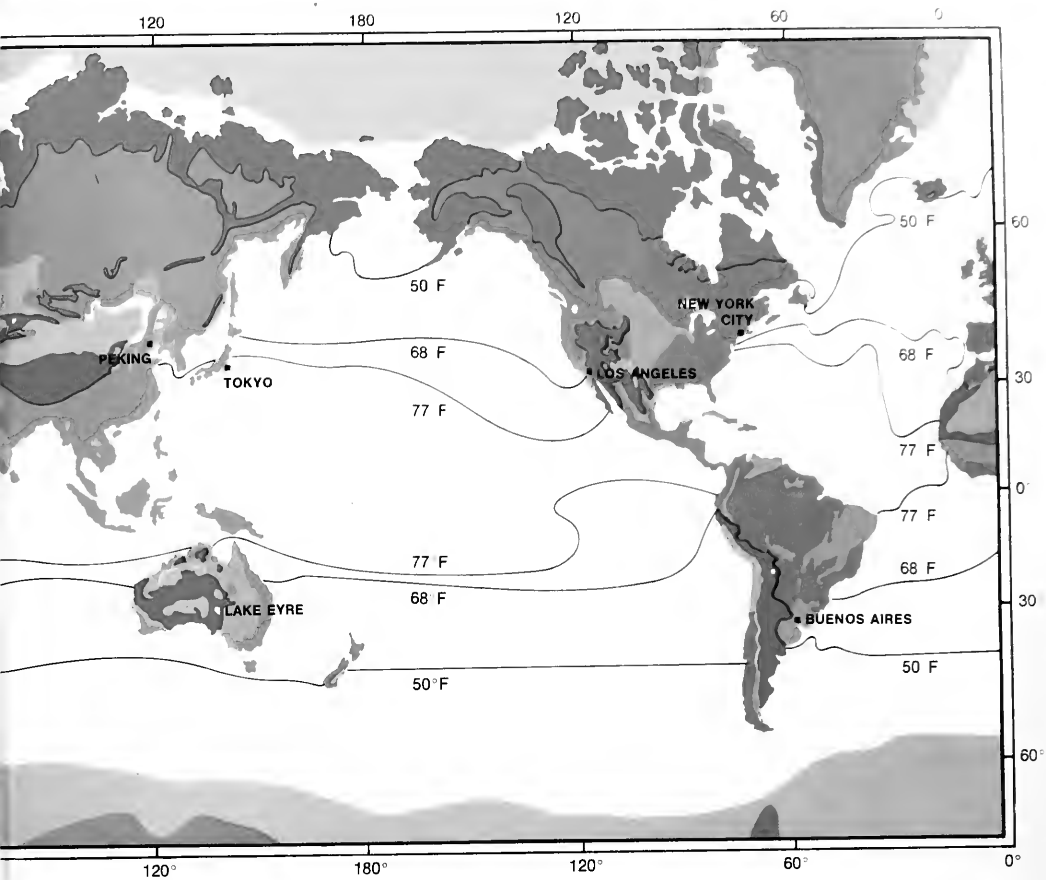
Some records indicate that the weather variability, especially over land in the high and middle latitudes, was greater. Winter was longer; spring, autumn, and summer were probably shorter; day-to-night temperature differences were bigger; and there were large day-to-day weather fluctuations. Strong winds blew relentlessly in the loess belts of Europe and Asia, the dune regions of South Australia, and off the west coast of Africa.

What caused such a climate? We still do not know. A more pertinent question might be, What causes the warm climate of interglacial intervals, such as the present one, which began about 10,000 years ago and is warmer than any of the preceding temperate oscillations of the past 100,000 years? Since glacial conditions clearly predominated during the past million years of the earth's history, the present interglacial interval is much more of a rarity than is a glacial episode.

Within the precision limits of radiometric dating, it has been established that relatively mild and cold episodes alternate in cycles of about 20,000, 40,000, and 100,000 years. The cold intervals coincide with times of northern spring perihelion and low tilt, whereas mild periods fall



Conditions pertain to summer in the Northern Hemisphere. Vegetative zones refer to potential vegetation without human interference.



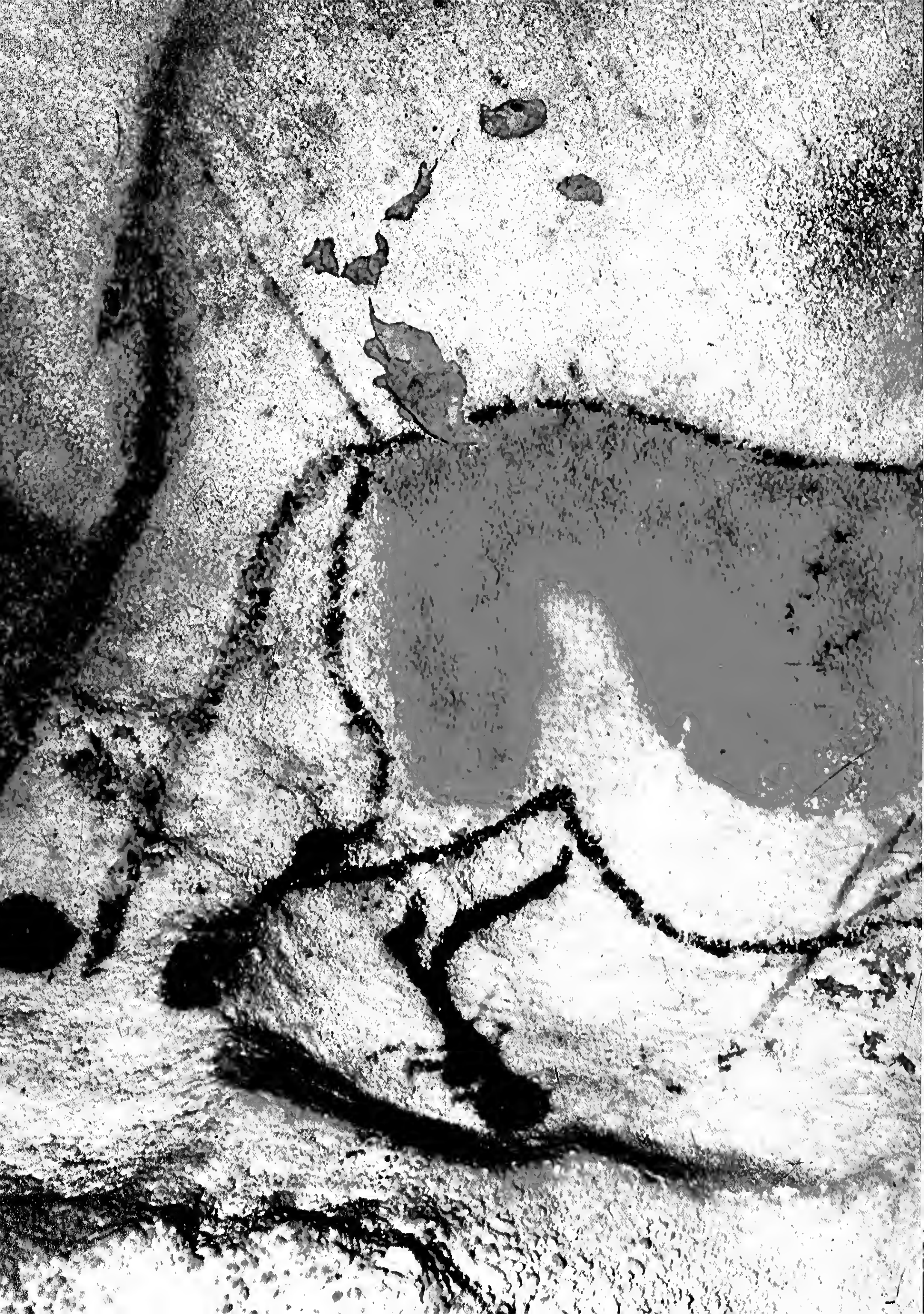
within the time of autumn perihelion and high tilt.

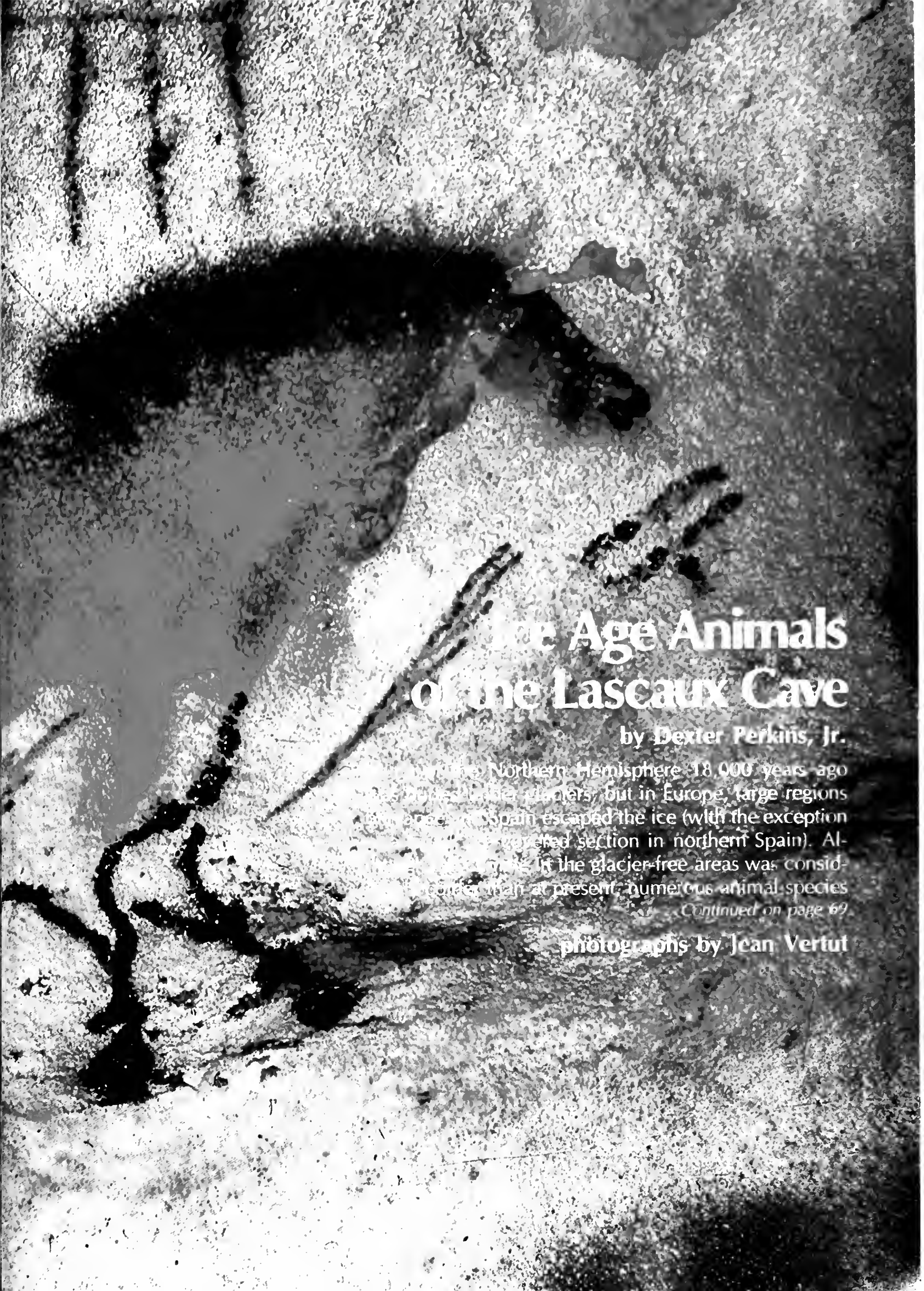
Perihelion is that point in the earth's annual orbit when the planet comes closest to the sun. Tilt is the inclination of the earth's rotational axis to the plane of the ecliptic, or the earth's path around the sun. When the tilt is high, about once every 40,000 years, both polar caps receive more sunshine than they otherwise do.

Whether the changing orbital parameters are the primary cause of the gross cold–warm climatic shifts is still undetermined. One hypothesis proposes that the seasonal snow and pack-ice fields could provide the mechanism linking orbital variations with climate. If the earth's closest approach to the sun occurs in the late summer or early autumn of the Northern Hemisphere, snow cover would, on the average, tend to build up later, leaving less accumulated snow to melt in the spring. Simultaneously, pack ice in the Antarctic Ocean (where it is spring) would dissipate more quickly. Pack-ice fields in both hemispheres would be smaller when the tilt is high and more solar radiation reaches the high latitude belts. One thing is certain, the variable extent of snow and ice has a critical influence on the amount of energy absorbed by the earth's surface and turned into heat. Only about 20 percent of solar radiation is absorbed by snow, while 80 percent is reflected back into space. The proportion is reversed at snow-free surfaces.

If a glacial climate is a more normal situation for the earth than the climate we have now and if cold periods reappear approximately every 20,000 years, what are the chances of another cold spell arriving within a few thousand years?

If only natural developments are taken into account, most scientists believe that we are headed on such a course. What we do not know, however, is to what degree human activity has already interfered with natural climate-forming forces and how that activity may interfere in the future. It is known, for example, that carbon dioxide produced by burning fossil fuels and the heat released in many industrial processes tend to warm the atmosphere. On the other hand, deforestation, overgrazing, and the release of dust into the atmosphere tend to produce a cooling effect. Thus, man may already possess the power to balance and control the climate and prevent future glaciations. □





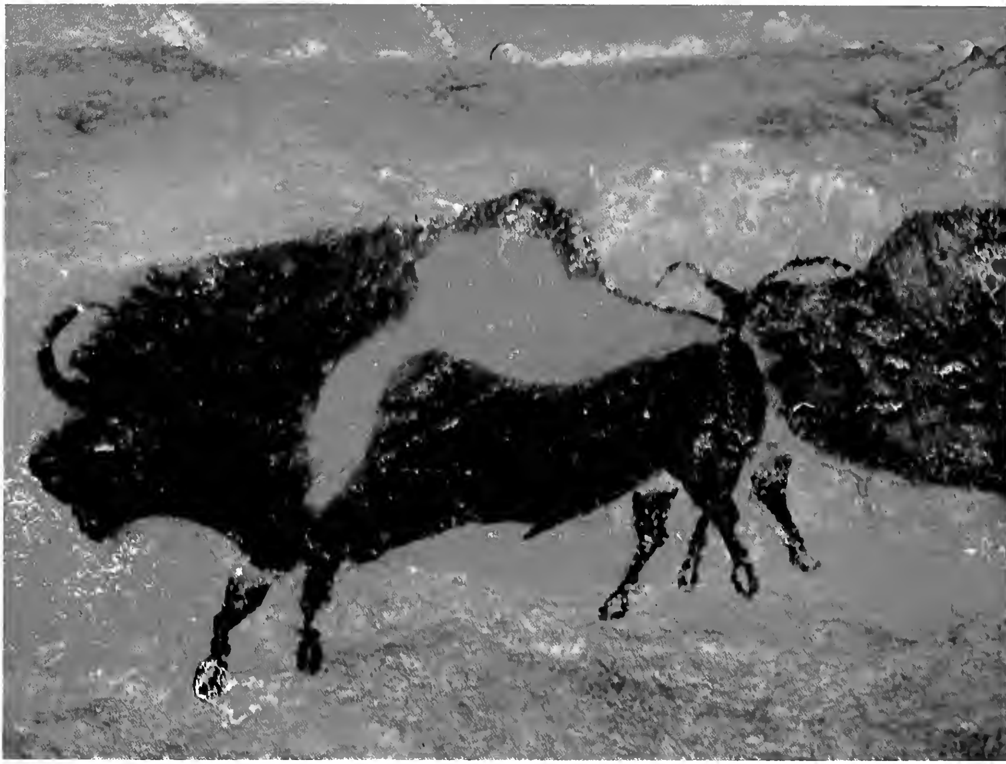
[illegible]e Age Animals [illegible] the Lascaux Cave

by Dexter Perkins, Jr.

[illegible] the Northern Hemisphere 18,000 years ago [illegible] glaciers, but in Europe, large regions [illegible] Spain escaped the ice (with the exception [illegible] section in northern Spain). Al[illegible] in the glacier-free areas was consid[illegible] than at present, numerous animal species

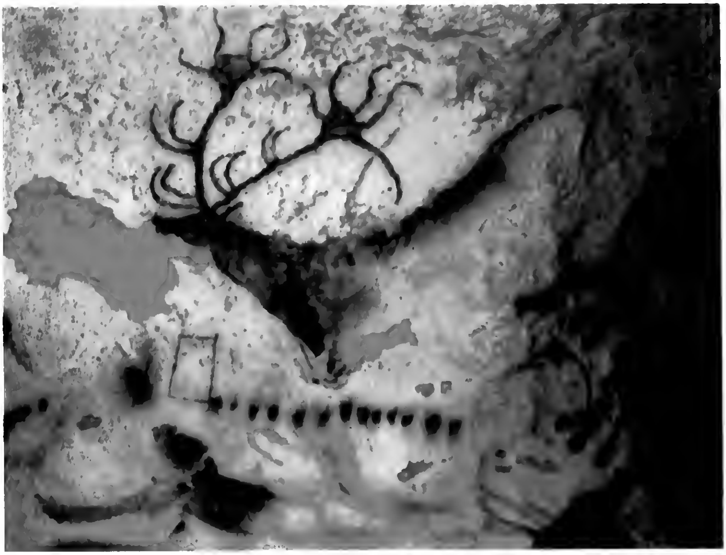
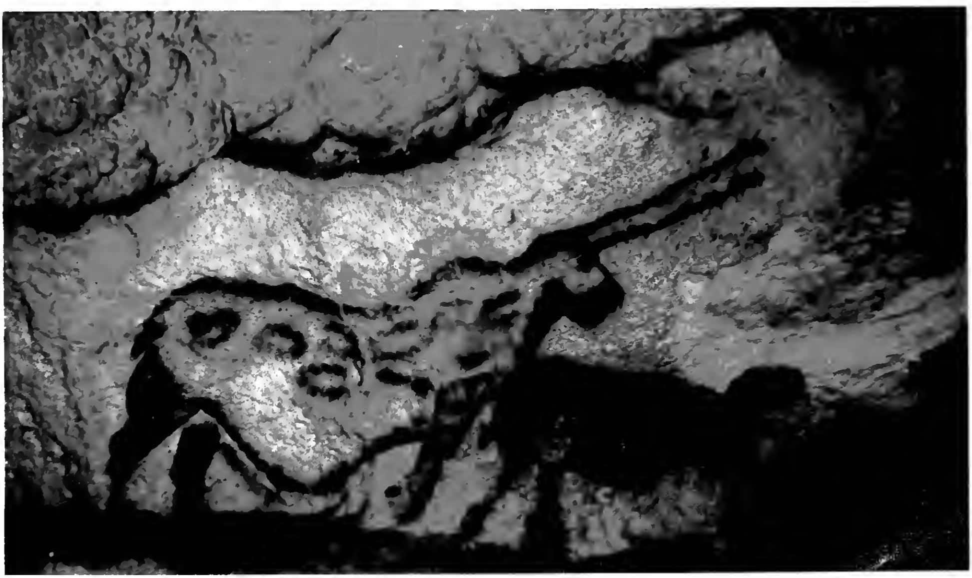
Continued on page 69

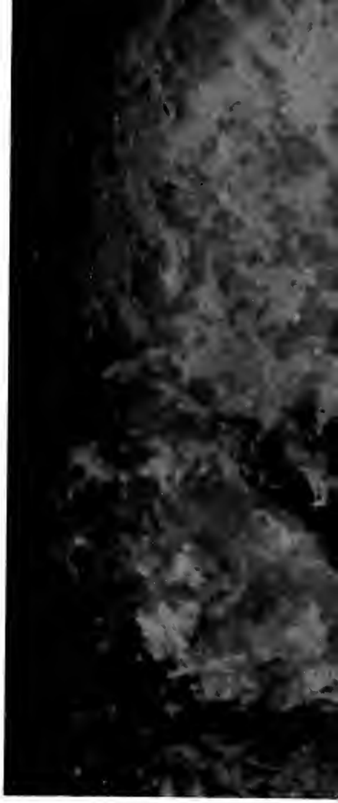
photographs by Jean Vertut



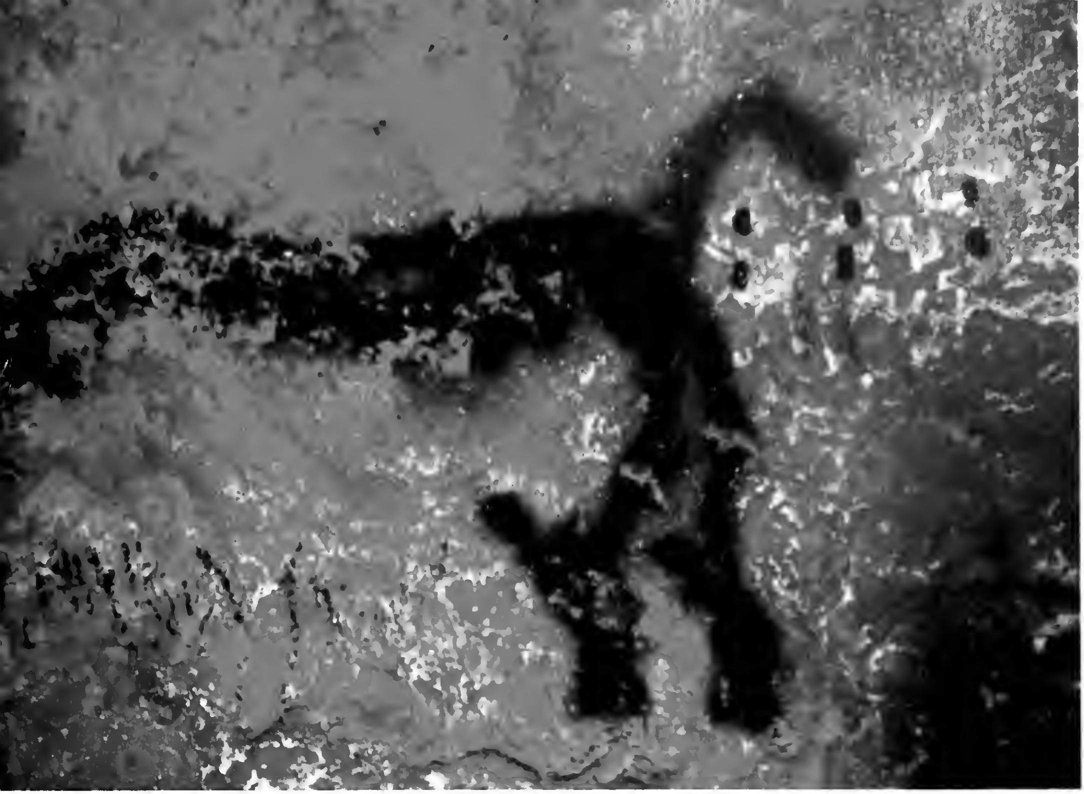
Only a few paintings depict the European bison, above, at Lascaux. These animals are common in cave art of a slightly later date. The bison at Lascaux are similar to the modern European bison but the horns are considerably longer. The paintings may be of a bison variety that once inhabited much of Europe and Asia, but which is now restricted to zoos and game preserves. The animal depicted at right is probably one of the fantasy creatures at Lascaux. However, the painting may be based on an actual species since the horns are similar to those of the chiru, an antelope species inhabiting the Himalayas in Tibet. The chiru has never been found in Europe. Both the paired brow tines and the flat areas between the upper tines of the stag, upper right, are typical of reindeer and fallow deer, but fossil red deer antlers also show these characteristics.

Previous page: Paintings of horses, all showing shaggy coats and erect manes, are common at Lascaux. They are similar in appearance and may be ancestral to Przewalski's horse, a breed still living in isolated herds in the steppes of central Asia and Mongolia.



The red deer, below, frequently painted on the walls of Lascaux, was probably one of the principal food sources of the inhabitants of the area. Now restricted to mountainous and forested regions of Europe and Asia, this deer species—of which the North American elk is a variety—formerly inhabited diverse environments.



The woolly rhinoceros is another species that, in the late Pleistocene, inhabited a number of climatic regions, extending from as far south as Spain and Italy, where temperate climates produced vast grasslands, to the tundra regions of the north and as far east as Alaska. Paintings of the woolly rhinoceros, above, are rare in the cave art of the upper Paleolithic period. In most caves, including Lascaux where there are two representations, the animals are painted in deep recesses. Closely resembling the Indian rhinoceros in size and shape, the woolly rhinoceros was usually depicted with head held low, an indication that it was a grazing animal.

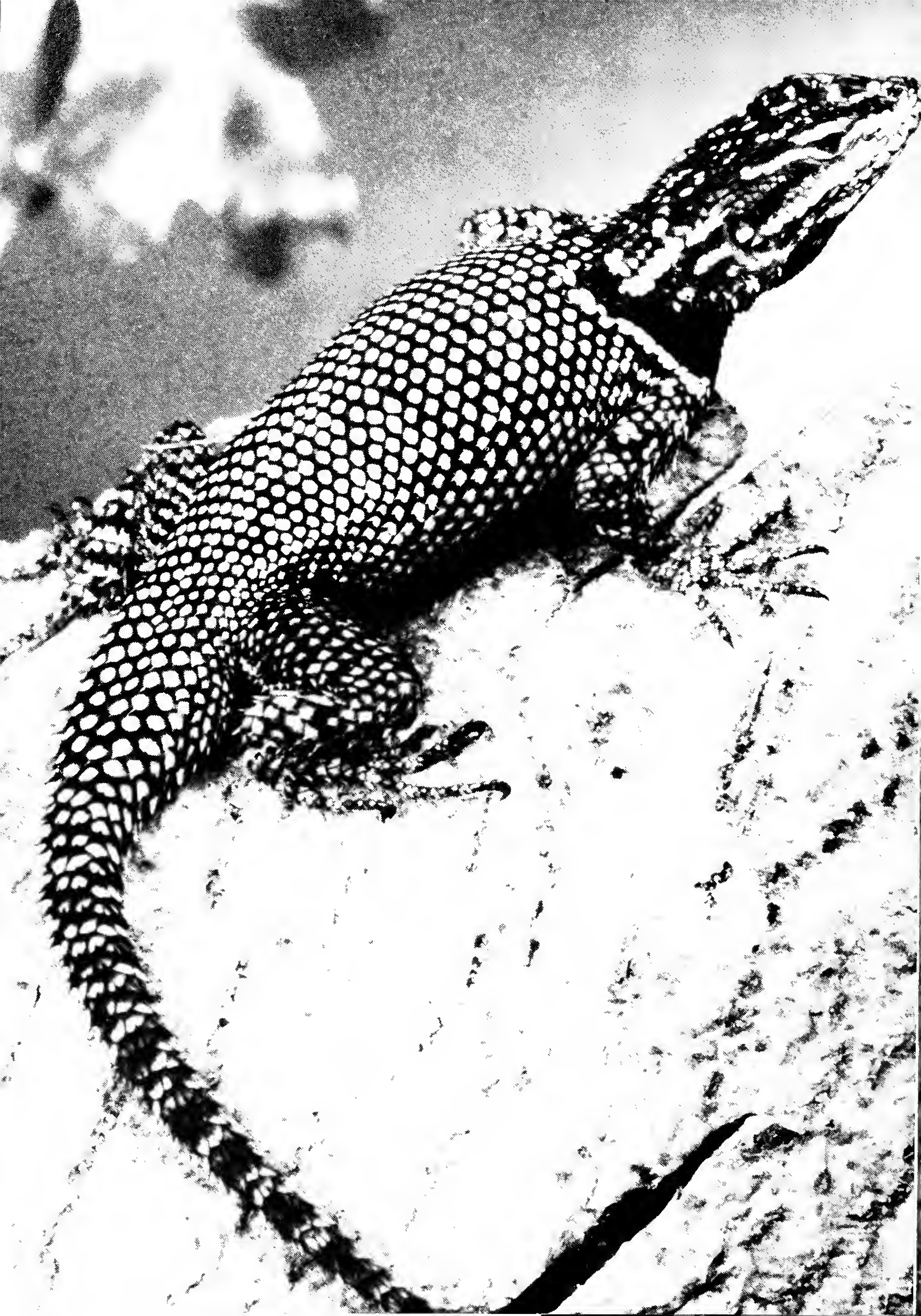
lived there. More than a hundred caves in both France and Spain testify not only to the presence of humans and other animal species during this time but also to man's artistic capabilities.

European cave art began long before the glaciation reached its height. The earliest evidence dates back some 30,000 years to rock carvings found in the Dordogne valley of France. Evidently the presence of the ice sheet to the north did not halt the evolution of cave art to the south. During the next 20,000 years the paintings and carvings became progressively more refined and detailed. The height of this sophistication is evident in the 12,000-year-old paintings of Altamira, a cave in northern Spain.

The paintings in the Lascaux cave in southern France, done some 15,000 years ago, show less refinement, yet the details of the artwork make it possible to recognize most of the faunal representations. From such identifications, we can determine some of the species present in Europe during the Ice Age and also learn which ones were hunted by man.

The meaning of the paintings has never been satisfactorily explained, and few scholars have found any rationale for them. Only a few species are represented: there are no small animals such as rabbits, foxes, or wolves, and several similar paintings depict the same animals. Yet selectivity of the subjects implies some type of order. After examining the topography of Lascaux, as well as that of other caves, French archeologist André Leroi-Gourhan concluded that the same species were usually painted in similar parts of each cave: bison, horses, and oxen in the central chambers; deer, mammoth, and ibex in outer areas; rhinoceros, lion, and bear in the farthest recesses. Beyond this ordering, the significance of the paintings remains a mystery.

In contrast to the detailed paintings of other fauna, cave representations of humans are frequently crude. This figure at Lascaux, painted opposite a depiction of a bison, is in one of the cave's deeper recesses. The meaning of the paintings of humans and the reason for their simplicity remain mysteries.



Lizard Coexistence in Four Dimensions

by Carol A. Simon

By eating different-sized prey, from different perches, at different times of day, some lizards reduce competition

Coexistence, when defined as the persistence of two or more species in one habitat, can develop through the evolution of differences in resource use. By locating food with different behaviors, and by feeding at different sites in the habitat or at different times of the day, coexisting species can divide their habitat's resources and avoid competitive exclusion.

An example of such resource partitioning was discovered by the late Robert MacArthur while conducting bird population research. He found that a number of different warblers living together in northeastern coniferous forests subdivide that particular habitat. Individuals of one species feed predominately near the treetops, those of another feed near the trunks, a third species utilizes the outermost portion of the branches, and so on. By reducing food competition, such resource division allows several species to coexist in relative harmony. Other studies have also shown that coexisting individuals of some species divide the resources of their habitat.

On a favored perch, a Yarrow's spiny lizard basks in the sun and watches for any potential prey that may wander into range.

Nathan W. Cohen

Yarrow's spiny lizard, *Sceloporus jarrovi,* shows such resource division. This species occurs in rocky areas, at elevations above 4,900 feet, in Mexico, southwestern New Mexico, and southeastern Arizona. These diurnal lizards usually perch on rocks, but they are occasionally found on trees, logs, or the ground. The perch sites are used for basking in the sun and as home range and territorial "outlooks" for spotting and pursuing intruding lizards, potential mates, and food. Yarrow's spiny lizards feed on a wide variety of small invertebrates, especially flies, beetles, ants, and grasshoppers.

I began my study of these lizards, particularly their division of resources, in 1972 in Arizona. Size selection of prey items, determined by stomach analyses, was the first aspect of partitioning I examined. I found larger animals eat larger food items than do smaller animals. As lizard body size increased, the average size of food items also increased. The smallest lizards ate insects and other arthropods that averaged one-fifth of an inch in length, while the largest ate prey averaging nine-tenths of an inch; lizards of intermediate size ate intermediate-sized prey.

It is relatively easy to hypothesize why prey size increases as lizard size increases. Since lizards swallow food whole, large food items are handled more easily by larger lizards. Also, since larger food items provide more energy than smaller ones, it is more efficient for a larger lizard to pursue a large insect rather than a small one.

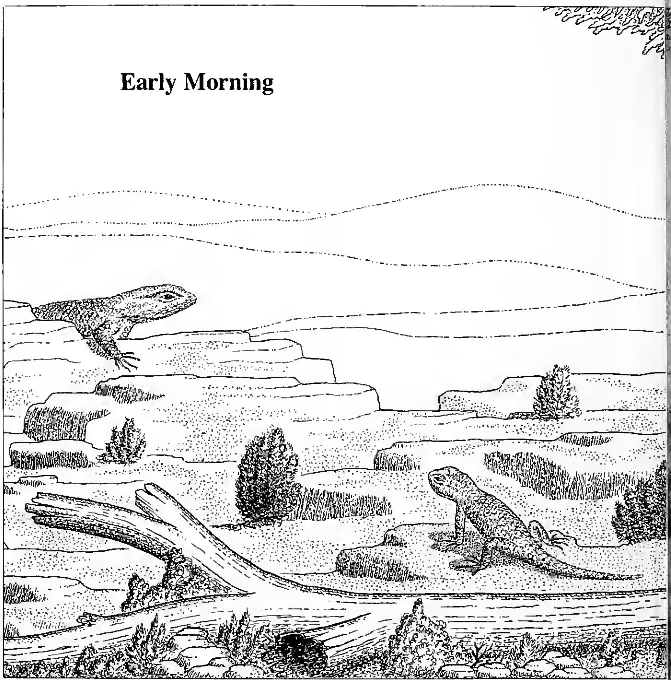
One aspect of prey size selection, however, was not as easily explained. When I compared the prey selection of male and female lizards, I found that, although food size for both male and female lizards increases with body size, females eat larger prey than similarly sized males. Males eat relatively smaller items and more of them.

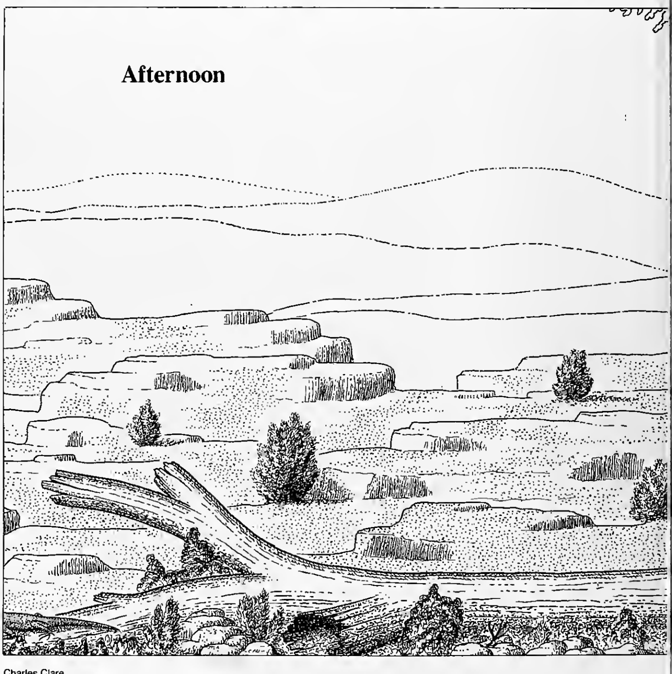
I can suggest several reasons why males and females of equal size select prey of different sizes. Concurrent studies indicated that individual Yarrow's spiny lizards are highly territorial. To various scientists and laypersons, the word *territory* connotes an entire spectrum of behaviors, but in this discussion, I refer to a phenomenon where each individual defends a specific area, or territory, within a larger home range.

Adult Yarrow's spiny lizards defend territories against adults of the same sex and all juveniles. Only adult male–female territorial overlaps occur, presumably so that efficient mating can take place. That only male–female overlaps occur provides an important clue for a possible advantage for male–female prey size differences. Since males and females maintain overlapping territories, they are competing for a portion of the same food supply. Males, however, consistently choose smaller food items than females. Because males and females are not pursuing the same potential prey items, feeding efficiency would be increased. Through

Resource Division in the Yarrow's Spiny Lizard—Perch Type, Time, Size, Sex

Competition between individuals of this species is reduced through a partitioning of resources. Larger individuals are active mainly in the morning and for only a few days a week; smaller lizards feed daily in the afternoon. Larger lizards eat larger prey than smaller individuals; females eat larger prey than males. Larger lizards occupy higher perches; females perch higher than males. Such partitioning results in a differential cropping of prey, and allows a greater number of individuals to coexist within a given habitat.





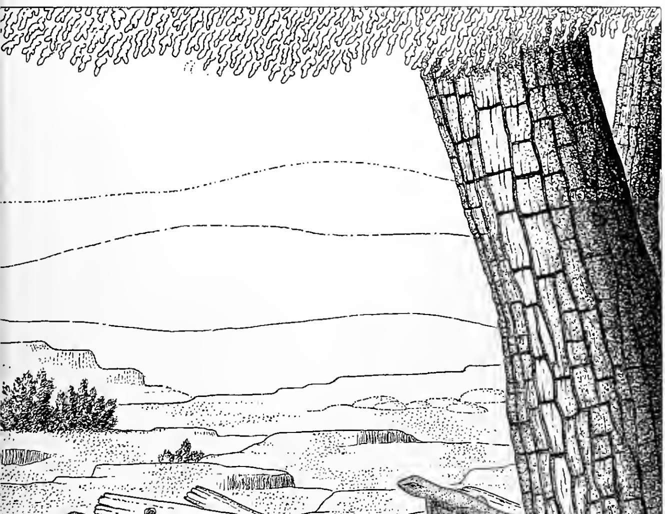
Charles Clare

natural selection, males probably acquired specializations for feeding on smaller prey while females acquired specializations for eating larger items.

Because males eat smaller prey items (but more of them), they use more energy for feeding. This arrangement seems most efficient in terms of reproduction, since the ovoviviparous female expends a great deal of energy for egg production and embryo growth.

Prey selectivity by males and females may be explained in another way. Microhabitat differences resulting from different perch choices could help explain intraspecific feeding variations. Lizards occupying perch sites near the ground are more likely to capture ground-dwelling insects; individuals on higher perches would have greater access to flying insects.

Individual lizards spend a great deal of time on their perches. Varying perch heights may result in certain lizards eating smaller or larger food items because of relative prey availability in different microhabitats, but it is more likely that food selection is based on available taxa rather than size. Prey items of a variety of sizes are found near all perch sites, but certain taxonomic groups are more pre-



-alent in one area. Situations where perch site selection results in increased accessibility to prey items of both a particular size and one taxonomic group are also possible. For example, a ground-perching lizard has access to large ant populations whereas a branch-perching lizard might not.

Even if perch differences are only a partial explanation for prey size selection, such microhabitat differences are potentially an important means of resource division. If Yarrow's spiny lizards of different sexes and sizes typically choose different perch sites, a pair of lizards occupying overlapping territories will not compete for exactly the same food. A male regularly choosing perch sites 1½ feet above the ground on a tree trunk and a female normally perching on a large rock about 13 feet above the ground would see, and have access to, different prey items.

In June 1974, I was joined in my work by George Middendorf, then a graduate student at Hunter College in New York. We began collecting data to determine whether individual lizards choose particular perch sites and whether these choices are characteristic of a particular size or sex.

Our first significant finding confirmed a correlation between lizard size and perch height. Larger lizards choose perch heights higher off the ground than smaller lizards, and males choose significantly lower perches than females of equal sizes. Variation in perch heights ranged from ground level to nearly 17 feet.

Four substrates—rocks, trees, logs, and the ground—were used as perch sites. Most lizards perched on rocks, but approximately 5 percent, always the smallest lizards, perched on logs, and approximately 5 percent of the males, always the largest, perched on tree trunks. Small percentages of lizards were found on other substrates. These perch substrate differences, in addition to perch height variations, may also be important for exposing individual lizards to different segments of the food supply.

The final aspect of resource partitioning that we examined was the difference in activity periods; time can be treated as a resource. Activity times may vary within or between species in such ways that different an-

imals are active at different times of the year or at different times of the day. The idea of intraspecific, temporal resource partitioning for a lizard had previously been considered only in theoretical discussions of resource division.

We used several techniques to determine temporal activity patterns of Yarrow's spiny lizards. We found that in the largest size classes all animals were most active early in the morning, with activity tapering off after midday. Also, these larger lizards were active for only a few days a week. Lizards in the smaller size classes were active primarily after noon and were active almost daily.

Here again we see a means of reducing competition for food. Certain segments of the population are active and feeding at different times of the day and even on different days. Although temporal partitioning for Yarrow's spiny lizards may have arisen for reasons other than the reduction of food competition, perhaps because of differing temperature requirements of different-sized lizards, the result is another form of resource division.

Having learned a great deal concerning the evolution of competition-reducing mechanisms from our studies of Yarrow's spiny lizards, we hope to apply our data on resource division to some of the broader questions ecologists are asking.

One question is, Does superabundance or scarcity of food result in changes in food selection, microhabitats, or activity periods? In other words, how does resource usage change under varying conditions and are these changes predictable? For example, if food abundance suddenly decreases, individual Yarrow's spiny lizards may no longer be able to select food items of a particular size. In order to avoid starvation, pursuit of many other sizes of food items would then be necessary. Individuals could shift to using many different perch heights, thus adding new portions of the habitat to their feeding efforts. Finally, it is possible that an individual lizard could obtain enough of the particular food it is best adapted for catching by remaining on its perch all day or every day.

But whatever combinations of resource use may occur under different conditions, partitioning of available food is an important adaptation for coexistence within a common habitat. □

Adults are territorial, defending their spatial boundaries against other adults of the same sex and all juveniles.

Carol Simon

Journey of a Seventeenth-Century Cannon

by Christopher L. Hallowell

Many of the artifacts found in the cellar hole of the World Trade Center were spirited away to private homes

With the excavation of the cellar hole for the twin towers of the World Trade Center in lower Manhattan almost a decade ago, many archeological odds and ends came to light that helped piece together a picture of New York's earliest years. As bulldozers and backhoes and men with picks and shovels gouged out a hole that was to cover ten city blocks, they unearthed clay pipes, teacups, delicate hand-blown bottles, shoes, coins, cannonballs, and ship's timbers—to name just a few artifacts.

During the early part of the excavations, archeologists and historians hoped that some of the ship's timbers would be those of the *Tijger*, one of the first ships documented as having anchored in New York harbor at the southern tip of Manhattan. The *Tijger* was a Dutch ship, owned by the Van Tweenhuysen Company and under contract to the Dutch East India Company to carry furs from the New World to Holland. The Dutch East India Company, a government-sponsored trading firm, monopolized this fur trade from 1602 to 1621. In 1614, just as she was to set sail for Amsterdam with her holds full of beaver and otter pelts purchased from the Indians, the *Tijger* caught fire and burned to the waterline (*see* "Disappearance of the Historic Ship *Tijger*," *Natural History*, August-September 1974).

Either her crew or other Dutch traders probably attempted to salvage the ship's remains by beaching them on the nearby bank of the Hudson River. Their success in using the timbers was evidently limited, however, for in 1916 a subway construction crew, digging the tunnel for the Seventh Avenue IRT line in lower Manhattan, came upon a ship's prow eighteen feet below the surface, just about where the shoreline of the Hudson River would have been in the seventeenth century. At that time, this bank of the river was about 250 yards east of where it is today, and the tunnel the subway crew hewed out followed the early shoreline.

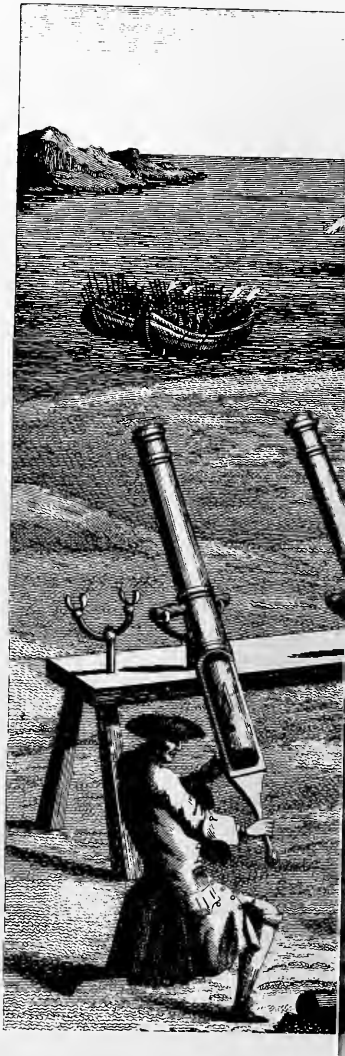
Historians theorized that the ancient timbers were those of the *Tijger*, and radiocarbon dating placed the wood at between 320 and 360 years old. Using mules, the subway workers attempted to pull the timbers from the tunnel wall, but they would not budge. As a result, they were sawed off where they disappeared into the cut. These timbers are now in the Museum of the City of New York.

More than fifty years later, when excavations for the World Trade Center cellar hole began just west of the IRT subway tunnel, archeologists speculated that the construction would unearth more of the ship's remains. Timbers were found which might have been those of the *Tijger*, but before archeologists could examine them, they were trucked away with a load of debris and dumped in a nearby landfill site.

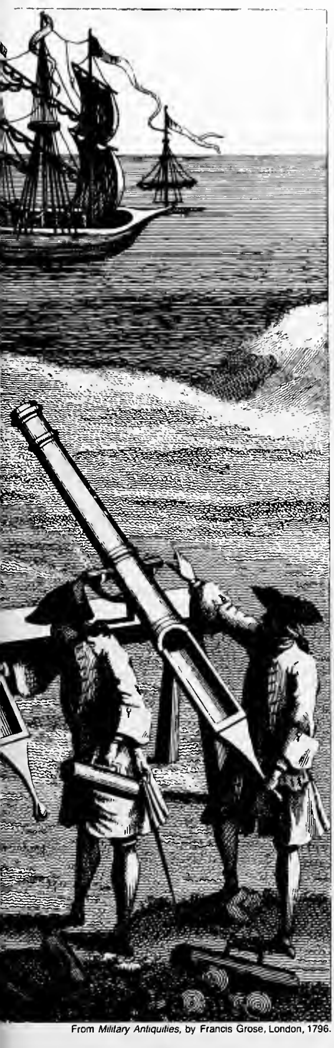
With the disappearance of these timbers, all hope vanished of ascertaining the existence of the *Tijger*'s remains. Ironically, however, a decade after the completion of the cellar hole excavation, another artifact has turned up, which, although not substantiating the site of the World Trade Center as the final resting place of the *Tijger*, strongly points in that direction.

The discovery also reveals the fate of many of the bits and pieces of the past that are dug up in construction sites. The finding of artifacts in such places is as much a reward to workmen as it is a curse to their employers. As workers waste thousands of dollars of company time sifting through debris in search of coins, bottles, and unusual bric-a-brac, their superiors see costs rising and construction schedules falling behind. But if artifacts are present, the workmen usually find them; regulations to prevent searching are almost impossible to enforce.

A market always exists for well-preserved artifacts and a number of workmen at the World Trade Center boosted their salaries by several hun-



dred dollars a week by selling their finds to collectors. This is true for other construction sites as well, and those artifacts that are not sold often end up decorating workmen's homes. Whether sold or used for decoration, such artifacts are rarely publicly displayed or subjected to scientific analysis. They merely disappear, and as far as enhancing our knowledge of history is concerned, they might as well have never been found.



From *Military Antiquities*, by Francis Grose, London, 1796.

But occasionally, such artifacts reappear. Their emergence from homes and private collections, where they can be appreciated by only a few people, is usually due to the concern of individuals well grounded in a knowledge of antiquities and with a desire to see artifacts made more accessible to the public.

During the excavations, work crews were always on the lookout for ancient cannons. Ships of that time usually carried some weapons, and the *Tijger* was reported to have carried six or eight large cannons. She may have also carried some smaller ones, which were not mentioned in the ship's records. The workmen were frequently inspired in their search by the discovery of cannonballs. But no cannons appeared at the World Trade Center site until the summer of 1967, when backhoes and bulldozers working in different areas of the cellar hole dug up three. Two were in perfect condition, except for ancient marine incrustations and some corrosion; the third had a chipped muzzle. All of them were small, about four feet in length, and weighed several hundred pounds apiece, according to Jim Hastie, a superintendent on the site when the cannons were unearthed.

The first two found were taken to the field office of West Street Associates, the consortium of five construction firms responsible for building the World Trade Center. They remained there for a time, then quietly disappeared. No one knows what happened to them, although several workmen remember seeing them in the midst of equipment that accumulated in the office.

As depicted in an eighteenth-century woodcut, cannons similar to the one found in the World Trade Center cellar hole could be easily maneuvered and fired.

Hastie clearly remembers the last cannon found because of its unusual design and well-preserved state. Its barrel was not one solid piece; instead, the top half of the breech had an opening into which a cylinder with a handle locked in place. Several workmen carried the weapon away from the immediate excavation area and laid it next to one wall of the cellar hole. Hastie recalls the piece was to be taken to the field office when the workers had a spare moment.

When the construction crews returned to work the next morning, however, the cannon was gone. And according to Hastie, one of the workers who had carried it to the cellar hole wall the day before did not report for work that day or ever again. Hastie believes that this person, a temporary employee, was responsible for the theft, but it was not of sufficient concern to anyone to have the man traced. The excavations proceeded and the matter was forgotten.

If the cannon had not turned up in the barn of an antique arms dealer eight years after it disappeared, only a handful of people would ever have been aware of its existence. Since being stolen, it had passed through the hands of three people, all of whom collect various kinds of antiques for personal pleasure and profit. Had it not been for the trained eye of an antique arms expert, the weapon might easily have continued along this route, known only to a select group of people.

One of the responsibilities of Harold L. Peterson, a curator for the National Park Service, is to locate antique arms and weapons suitable for historic monuments administered by his agency. The job entails sporadic visits to antique arms dealers to look over their collections. Last fall, Peterson, while driving through Connecticut on business, decided to stop in the small village of New Milford to view the collection of Norman Flayderman, an antique arms dealer

with one of the largest collections in the country. Stored in a renovated barn, Flayderman's collection includes cannons, rifles, and pistols, as well as halberds, swords, crossbows, and other martial paraphernalia, strewn about the floors and hanging from the walls of the building.

Amid this awesome collection of weaponry gathering dust on the floor of one of Flayderman's back rooms, a small bronze cannon with a handled cylinder that fit into the breech caught Peterson's eye. Although this type of cannon is now rare, Peterson realized the uniqueness of the piece by the insignia of the Dutch East India Company etched into the breech chamber.

Known as a sling piece or a port piece or sometimes as a murderer, this type of cannon was common in Europe on both land and sea from the fifteenth to the seventeenth centuries. In this country also, settlers used such cannons at Plymouth and Jamestown. Mounted on a fulcrum and easily rotated by one person, they were valued for rapid firing and close-range effectiveness.

Their partially hollow cylinders—called breech chambers—could be filled with gunpowder and used in any cannon of appropriate size and design. A number of these chambers could be loaded and stored in readiness. The process of firing these weapons was simple and quick: a ball placed in the breech was followed by a chamber that was locked into place; when the powder was ignited and the cannon fired, the used chamber was removed, and replaced with another ball and another loaded chamber.

Peterson was not interested in buying the cannon for the park service, but mentioned his find to Joseph Noble, director of the Museum of the City of New York. In October 1975, the museum purchased the weapon for $4,500; it is now being prepared for public display.

Flayderman deals in antique weapons as much for his interest in their history as to make a profit on their sale. Having established a reputation for his extensive collection in the early 1950s, Flayderman, a fast-talking and sharp businessman, can afford to pay high prices for unusual artifacts. And because he carries a large inventory and is in the antique arms business partly for pleasure, he can also afford to wait until the price is right before selling a piece.

In 1973, Flayderman bought the cannon from Stanley Lambert, a

Long Island antiques dealer. Flayderman will not say how much he paid for it, only that he "turned quite a profit on it" when he sold it to the museum. Stanley Lambert, who owns Lambert Antiques and Collectables in Huntington, Long Island, does not have a reputation to match Flayderman's. He deals mostly in antique furniture and sculpture, but when two of his friends in the Long Island Antique Gun Club offered to sell him the cannon early in 1973, he bought it on a gamble, hoping that he could turn it around and make a large profit. It was the Dutch East India Company insignia that encouraged him to take the chance.

Lambert's clientele, however, was not primarily interested in antique arms and apparently did not respond to the new acquisition displayed in his small store. Only a month after he purchased the piece, Lambert loaded it into the back of his car and drove to New Milford, where he sold it to Flayderman. Despite the quick turnover, he says he made several hundred dollars on the sale.

Obeying an informal agreement among antiques dealers that the immediate origins of some merchandise remain confidential, Lambert will not divulge the names of his Long Island Antique Gun Club friends from whom he bought the cannon. He did say, however, that these two people had purchased the weapon through a classified advertisement in the *New York Times* that offered the cannon for sale. According to what Lambert's friends told him, the advertisement had been placed, and the cannon sold, by a man who said he had found it in the cellar hole of the World Trade Center.

Although the cannon does not confirm the existence of the *Tijger*'s remains, its insignia marks it as being one of the earliest signs of European activity in this country. For this reason alone, it should be highly valued. Yet, had it not been for the discerning eye of Harold L. Peterson, the cannon might still be in the hands of collectors or dealers, where its value and significance would be lost to the public. Unfortunately, until archeologists are able to watch closely over construction sites that might yield historical evidence, this will be the fate of most artifacts unearthed in the debris of cellar hole excavations. ☐

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Destruction of the Earth-Moon System

One scenario for the end of the world includes the breakup of the moon into pieces that will form a ring around the earth

When observing the endless ebb and flood of the tides, one is aware of some vast interplay of forces in nature that nothing can stop. Even the mightiest tidal waves appear to be far too weak to affect the earth or the moon in any appreciable way. And yet this sometimes gentle, sometimes violent, breaking of waves against the shores does indeed affect the earth, and in such a way that ultimately the earth-moon system, as we now know it, will be destroyed.

Anyone who has lived at the seashore or spent a few days there watching the ocean knows that successive high tides occur about 12.5 hours apart. The two high tides, which occur at about the same time on successive days, are on the average separated by 24 hours and 51 minutes. Since the average interval of time between two successive risings of the moon is also 24 hours and 51 minutes, one correctly infers that the tides and the moon are closely related. This was first pointed out by Newton, who developed a simple, but correct, theory of the tides based on the moon's gravitational attraction.

Although the moon is largely responsible for the tides, the sun also contributes. The sun's contribution to the tides is slightly less than half that of the moon, even though the gravitational pull of the sun on each particle of water is about 180 times greater than that of the moon. Despite the moon's weaker gravitational pull, its tide-raising ability is about twice that of the sun. It is not the total gravitational pull that counts in raising tides; rather it is the difference between the pull on a particle of water on the side of the earth facing the moon and that on a particle on the other side of the earth. This difference is twice as pronounced for the moon as for the sun because the moon is so much closer to the earth.

To see this, note that a one-gram particle of water on the earth directly beneath the moon, being closer to the moon than is the center of the earth, is pulled more strongly toward the moon than a one-gram particle of matter at the center of the earth. Thus, the oceans directly beneath the moon are pulled away from the earth as a whole, thereby forming a high tide. On the other hand, a particle of water on the opposite side of the earth, being farther away from the moon than is the earth's center, is pulled less strongly than a similar particle at the center of the earth. The earth as a whole is thus pulled away from the water on the side farthest from the moon, causing this water to collect into another high tide.

As the earth rotates, bringing different parts of the oceans and the continents under the moon, the tides move around the oceans like a long, low wave with one of its crests beneath the moon and the other on the opposite side of the earth. A person standing on an island watching the moon rise observes the water rising

by Lloyd Motz

on the eastern side of the island first, then on the southern shore, and finally, on the western shore; as the moon sets, the water recedes from the western shore.

In the deep oceans the tides are essentially a surface phenomenon, so that there is very little friction between the water and the ocean bottom, but along the continental shorelines there is considerable friction as the water rushes over and then recedes from the dry land. This friction converts the mechanical energy of the water into heat. But since the tides obtain their kinetic energy from the earth's rotational energy, it follows that the constant flow of the tides is decreasing the rate of rotation of the earth and thus lengthening the day. In a sense, the tides are acting like a huge brake on the earth, slowing it down by friction, just the way the brakes of a car slow down the wheels.

Although the tidal slowing down of the earth is extremely small and the lengthening of the day is very gradual, it can be measured with great accuracy by comparing the times of eclipses in recent years with those recorded in antiquity. There is a marked discrepancy between the two if one assumes that the earth has always been a steady timepiece—that is, that the rate of earth's rotation has not changed during the last 4,000 years. From the discrepancy between the observations and the theoretical predictions of eclipses, one deduces that the rate of rotation of the earth has been decreasing and that the length of the day is now increasing at the rate of about a thousandth of a second per century. The rate at which the rotational energy of the earth is dissipated by the tides in this way is more than

2 billion horsepower, or very nearly 2 billion kilowatts.

The importance of this for the future of the earth-moon system is that the rotational angular momentum that the earth loses as its rotation slows down is transferred to the moon's orbital motion; in slowing down the earth's rotation by dragging the ocean waters, the moon gains the angular momentum lost by the earth and is thus propelled forward in its orbit. This results in a steady recession of the moon from the earth, a steady increase in the size of the moon's orbit, and a steady increase in the length of the month.

The rate at which these things are happening and the general dynamical features of the earth-moon system in both the past and the future can be computed from the rate at which the length of the day is now increasing. About 4 billion years ago the moon was approximately 10,000 miles away from the center of the earth, the earth rotated once every five hours, and the month was slightly longer than one day. The present length of the day and month and the present structure of the earth-moon system are the result of tidal action during the last 4 billion years. The earth-moon system will go on changing slowly in the same way until the length of the month and the length of the day are both equal to 47 of earth's present 24-hour days. When that happens, the earth will always keep the same face toward the moon, so that the moon will be continuously visible from one side of the earth only, neither rising nor setting. But because of the very slow frictional action of the tides, this will not happen for many billions of years.

Although the moon will then no longer cause the tides to rise and fall, producing, instead, an unchanging double bulge of the oceans, the sun will, and this solar action will slow the earth's rotation still further until the day becomes longer than the present month. At the same time, the moon will start approaching the earth again, while the earth and the moon together recede from the sun. Thus, the month will get shorter, while the day and the year will get longer. This process will continue until the moon's distance from the earth's center is less than 10,000 miles, which is a critical distance for the moon, known as the Roche limit. At that distance the tidal action of the earth on the moon will tear the moon into

pieces that will form a ring around the earth. There is strong evidence that the rings around Saturn were formed in this way when one of Saturn's moons came too close to that planet.

Before the moon is destroyed by the earth's tidal action, the moon itself will raise huge tides on the earth and alter the earth's structure enormously. The tide-raising force of the moon increases rapidly as it approaches the earth. At a distance of 10,000 miles, the moon would be about twenty-four times as close to the earth as it is now, and its tidal action would be about 15,000 times as great. The ocean tides at their maximum on the earth would then be hundreds of feet high and would completely inundate all the land masses in their path as they followed the rising moon. But this would not be the worst of it, for the moon would distort the entire earth by producing large tidal waves within the earth's rocky crust and in the underlying regions. These structural tidal waves, rushing through the earth's interior, would set off vast earthquakes and volcanic eruptions. Although the earth itself would not be destroyed by such cataclysms, all terrestrial life would probably perish.

In time, after the earth had torn the moon into pieces, the violent eruptions and tremors on the earth would cease, the oceans would recede, and life would probably begin to develop again on the dry land. But this would still not be the end of the "tidal evolution" of the earth; because of the sun's tidal action, the length of the day would continue to increase until it became as long as the year, which would then be a few weeks longer than it is now. The earth would then present the same face to the sun at all times, so that one half of the earth would be in perpetual darkness. The side of the earth facing the sun would become an unbearably hot desert, while the dark side would be covered with vast sheets of ice thousands of feet thick. These two forbidding hemispheres would be separated by a narrow zone (perhaps a few hundred miles wide) where intelligent life could exist. But the full series of these events will probably never occur because the time involved is so great that the sun itself will have changed drastically long before the lengths of the day and the year become equal.

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Additional Reading

Persepolis (p. 36)

Donald N. Wilbur's *Persepolis: The Archaeology of Parsa, Seat of the Persian Kings* (New York: Thomas Y. Crowell, 1969) is a succinct, semipopular account of the monuments and history of Persepolis. In *Persia: From the Origins to Alexander the Great* (London: Thames & Hudson, 1964), archeologist Roman Ghirshman—perhaps the most distinguished living authority on the subject—presents Iranian prehistory in an art-book format. Ghirshman has also published a more concise paperback book: *Iran* (Baltimore: Penguin Books, 1954). Historian Arthur T. Olmstead's *History of the Persian Empire,* originally published in 1948, is now available in soft cover (Chicago: University of Chicago Press/Phoenix Books, $5.95). An authoritative and detailed history of the Achaemenid period, Olmstead's book remains the standard English-language introduction to matters Iranian. In an earlier *Natural History* article, "The Shreds of Ancient Persia" (1969, vol. 78, no. 5, pp. 26–35), Bernard Goldman discusses the origins of the art found at Persepolis.

Royal Terns (p. 46)

Considered a classic on both sides of the Atlantic, *The Herring Gull's World,* by Nobel laureate Niko Tinbergen (Garden City: Doubleday/Anchor Books, 1967, $2.95), is perhaps the *one* best introduction to the study of social behavior in birds. For another elegant study of colonial seabirds, see Hans Kruuk's monograph "Predators and Anti-predator Behavior of the Black-headed Gull" (*Behaviour,* 1964, Supplement 11, pp. 1–129). Also recommended are George and Anne Marples's *Sea Terns or Sea Swallows: Their Habits, Language, Arrival and Departure* (London: Country Life, 1934) and W. Bickerton's *Home-Life of the Terns or Sea Swallows* (London: Witherby, 1912). Two recent behavioral texts strongly emphasizing field work are E.O. Wilson's *Sociobiology: The New Synthesis* (Cambridge: Harvard University Press, 1975), which incorporates the tern studies of Paul and Francine Buckley, and Jerram L. Brown's *The Evolution of Behavior* (New York: W.W. Norton, 1975), which presents ethology from an evolutionary viewpoint. For background information on the ecological principles discussed by the Buckleys, see C.J. Krebs' *Ecology: The Experimental Analysis of Distribution and Abundance* (New York: Harper & Row, 1972) and David Lack's *Ecological Adaptations for Breeding in Birds* (London: Methuen, 1968). A detailed account of some of the Buckleys' research was published in the technical journals *Ibis* ("The Breeding Ecology of Royal Terns," 1972, vol. 114, pp. 344–359) and *Animal Behaviour* ("Individual Egg and Chick Recognition by Adult Royal Terns," 1972, vol. 20, pp. 457–462).

Ice Age (p. 56)

Richard F. Flint presents an up-to-date description of glacial features and Pleistocene stratigraphy in his text *Glacial and Quaternary Geology* (New York: John Wiley and Sons, 1971). This book and J. K. Charlesworth's two-volume work *The Quaternary Era* (New York: St. Martin's Press, 1966) include extensive bibliographies. The latter is a 1,700-page compilation of data, detailing the past two million years of earth history. Paleobotanist Burkhard Frenzel's classic German work *Climatic Fluctuations of the Ice Age* is now available in English (Cleveland: The Press of Case Western Reserve University, 1973). It is concerned primarily with the glacial-age distribution of plants in Eurasia and the construction of maps based on flora-distribution data. *Pleistocene Geology and Biology, with Special Reference to the British Isles,* by R. G. West (New York: John Wiley and Sons, 1968), emphasizes biological features, devoting special attention to the history of plants as revealed in fossil pollen. P. S. Martin and H. E. Wright, Jr., have edited a volume, *Pleistocene Extinctions: The Search for a Cause* (New Haven: Yale University Press, 1967), which deals with the extinctions of mammals in many parts of the world at the end of the Pleistocene epoch. Romuald Schild's article, "The Final Paleolithic Settlements of the European Plain," in *Scientific American* (1976, vol. 234, pp. 88–99) examines evidence for changes in European climate and flora and fauna (as well as advances in the technology and social organization of the area's indigenous hunters) at the time of the final glacial retreats. The thirty-two members of the CLIMAP project referred to in this month's *Natural History* have written their first report of some of their findings; it was scheduled to be published in the March 26, 1976, issue of *Science*. The article, entitled "The Surface of the Ice-Age Earth," describes their multi-disci-

plinary methodology in more detail and discusses some of their early conclusions. Ian Cornwall, an environmental archeologist, addresses *Ice Ages: Their Nature and Effects* (New York: Humanities Press, 1970) to natural science and archeology students, but defines technicalities for the general reader.

Lascaux Cave Paintings (p. 62)

For a lavishly illustrated work on Paleolithic art see André Leroi-Gourhan's *Treasures of Prehistoric Art* (New York: Harry N. Abrams, 1967). Leroi-Gourhan attempts a reclassification of the evolution and styles of cave paintings and engravings; his work is of particular value for its tabulation of motifs, diagrams of cave layouts, and site index to individual caves. He has summarized much of this important work in a beautifully illustrated article in *Scientific American* "The Evolution of Paleolithic Art" (1968, vol. 218, no. 2, pp. 59–70). Examples of detailed works dealing with Lascaux cave are Ferrand Windels's *The Lascaux Cave Paintings* (New York: Viking Press, 1950) and Georges Bataille's *Lascaux: The Birth of Art* (Lausanne: Skira, 1955). Another volume, available as an inexpensive paperback, is *Lascaux: Paintings and Engravings*, by Annette Laming (Baltimore: Penguin Books, 1959). Nancy K. Sandars, in *Prehistoric Art in Europe* (Baltimore: Penguin Books, 1968), seeks to place the art of Paleolithic man in the context of his experience and spirituality. This author also treats the technical problems of representation and perspective encountered by the Paleolithic artists and by us in our attempts to understand their efforts. In *Pleistocene Fauna of Europe*, paleontologist Bjorn Kurten (Chicago: Aldine Publishing, 1968) reviews the animal life present at the time of the cave paintings.

Lizard Feeding (p. 70)

Peter H. Klopfer's *Habitats and Territories* (New York: Basic Books, 1969, \$3.95) introduces ecological and behavioral concepts concerning the use of space by animals and offers insights into the relationships between physical, biological, and social factors of territoriality. "The Evolution of Diversity in Avian Territorial Systems" (*Wilson Bulletin*, 1964, vol. 81, pp. 160–169) and "Territorial and Population Regulation in Birds" (*Wilson Bulletin*, 1969, vol. 81, pp. 293–329) are reviews by Jerram L. Brown describing the variability and advantages of territorial adaptations. A.S. Rand's "The Adaptive Significance of Territoriality in Iguanid Lizards," in *Lizard Ecology*, edited by W.W. Milstead (Columbia: University of Missouri Press, 1967, pp. 109–115), and Carol Simon's "The Influence of Food Abundance on Territory Size in the Iguanid Lizard *Sceloporus jarrovi*" (*Ecology*, 1975, vol. 56, pp. 993–998) deal specifically with this aspect of reptilian behavior. A section entitled "How Food and Space are Shared Between Species", in the 2nd edition of P.H. Klopfer's *Behavioral Aspects of Ecology* (Englewood Cliffs: Prentice-Hall, 1972), is concerned with competition and resource sharing by animals. A recent article by T.W. Schoener, "Theory of Feeding Strategies" (*Annual Review of Ecology and Systematics*, 1971, vol. 2, pp. 369–404), reviews the techniques animals use in food gathering.

Seventeenth-Century Cannon (p. 76)

Christopher L. Hallowell's "Disappearance of the Historic Ship *Tijger*" (*Natural History*, 1974, vol. 83, no. 7, pp. 12–26) provides a good overview of the times of the Dutch settlers and the naval vessel from which the artifact he now describes apparently came. Historian Isaac Newton Phelps Stokes, in the first of his six-volume work, *The Iconography of Manhattan Island* (New York: R.H. Dodd, 1915–28), gives extremely detailed background information gleaned from original records of the exploration and settlement of what became New York City. *Round Shot and Rammers*, by Harold L. Peterson (Harrisburg: Stackpole Books, 1969, \$9.95), is a short, readable introduction to the history of artillery pieces and their use. Other relevant titles are: *Guns, Sails and Empires*, by Carlo M. Cipolla (New York: Pantheon Books, 1966), *The Evolution of Naval Armament*, by F.L. Robertson (London: H. T. Storey, 1968), and *Age of Great Guns: Cannon Kings and Cannoneers Who Forged the Firepower of Artillery*, by Frank E. Comparato (Harrisburg: Stackpole Books, 1965). For a detailed account of the state and art of archeological theft, including the "fencing" of historical treasures and their acquisition by museums, galleries, and collectors, see Karl E. Meyer's *The Plundered Past* (New York: Atheneum Publishers, 1973, \$12.95).

Gordon Beckhorn

Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun, moving through the constellation Pisces during most of April, enters Aries about April 19 and moves into Taurus by mid-May. It moves from 4.5° north of the equator on April 1 to 15° by the end of April, but its northerly movement slows noticeably in May. On April 29, it keeps a date with the new moon to produce an annular solar eclipse.

The moon's phases are almost perfectly synchronized with the weeks during April and May. First-quarter comes on the 7th day of both months; full moon on the 14th of April and the 13th of May; last-quarter on the 21st and 20th of April and May, respectively; and new moon on April 29 and May 28. The moon is thus an evening object for the first two weeks of both months and a morning object from about mid-month on.

Stars and Planets This is the season to let the Big Dipper introduce you to the spring stars. The constellation is high overhead in the northern mid-latitudes early in the evening, and imaginary lines drawn through its easily recognized stars lead to the North Star (Polaris); the bright stars Regulus, Arcturus, and Spica; and the constellations Corona Borealis and Hercules.

The Star Map shows Mars and Saturn, our best evening stars this month, close to one another in Gemini. Jupiter (also an evening star), Venus (a morning star—but a poor one), and Mercury (going through a very favorable evening elongation) are below the horizon at the time of the map. Mars and Saturn will be most interesting to watch in the first week of May, when Mars moves into line between the planet Saturn and the stars Pollux and Castor (the bright "twins" of Gemini), and the waxing crescent moon moves through the group. Elusive Mercury will offer one of its better chances for viewing, low in the west-northwest after sundown, from about April 20 to the end of the month.

April 7: Observers along the East Coast should watch Mars with binoculars or telescopes tonight from 7:30 on, to see it approach and cover (an occultation) the third-magnitude star Epsilon Geminorum (about one-fourth as bright as Mars). The occultation lasts about 5 minutes, starting at about 8:00 P.M., EST.

April 14: Perigee moon comes 4 hours before full, and will affect tides today and tonight.

April 22: The weak, dim Lyrid meteors reach maximum.

April 25: Change to daylight time.

April 27: The moon is at apogee; Jupiter, in conjunction with the sun, enters the morning sky; and Mercury, at its greatest easterly elongation, is favorably placed as an evening star, low in the west after sundown.

April 29: A partial eclipse of the sun will be visible in North America—at sunrise—along the northeast coast.

May 4: The bright but weak (20 per hour) Eta Aquarid meteors reach maximum shortly before midnight.

May 4–5: The waxing moon is moving below Mars and Saturn.

May 9: Mercury is stationary and begins to retrograde.

May 11: Three conjunctions occur today: Venus with Jupiter; the moon with the star Spica; Mars with Saturn.

May 12: Perigee moon will enhance spring tides again tonight and tomorrow, coming about 24 hours before full moon.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 10:20 P.M. on April 15; 9:20 P.M. on April 30; 8:25 P.M. on May 15; but it can also be used for an hour before and after those times.

Helmut Wimmer

Feral Children

WOLF CHILDREN AND FERAL MAN, by J.A.L. Singh and Robert M. Zingg. *Archon Books, The Shoe String Press, Inc., Hamden, Connecticut 06514, $16.00; 379 pp., illus.*
THE WILD BOY OF AVEYRON, by Harlan Lane. *Harvard University Press, $15.00; 384 pp., illus.*

Freud assumed (and spent a lifetime showing) that the odd or peculiar, even the downright bizarre, can be quite helpful in understanding the so-called normal. His troubled, mostly middle-aged and almost exclusively middle-class Viennese patients, some of them strange and some of them on the brink of madness, gave him all sorts of ideas about those millions of others who live out their lives undramatically and with no apparent need of psychiatric intervention. Still, as he saw it and as other psychoanalysts still see it, the wild ravings of the craziest patient are not all that alien to the mental lives of the most sober, composed, "well-adjusted" men and women. In our dreams or nightmares, in those ever so evanescent "passing thoughts," we reveal ourselves as greedy anarchists—lusty beyond all propriety, "animallike," as the saying goes. And for years psychoanalytic theorists have emphasized this one aspect of man—the "seething cauldron" of the Id, which is where instincts, impulses, and untamed desires reside and strive to make themselves felt.

Freud saw us to be inevitably conflicted. If we are animals, in part, we are also civilized men and women—or try hard to be every day. Before psychoanalysis was developed as a way of seeing man's nature and predicament, philosophers like Rousseau and Hobbes struggled with similar dilemmas: how to describe this creature, man, who walks upright, thinks, speaks, is so separate from other life (so he has often proclaimed), and yet who—as Darwin pointed out—seems to have animal kin of sorts, not to mention a bestial side, as every day's news more than proves?

Hobbes chose to emphasize the power of the craven. We are "brutish," and only a variety of restraints keep us within relatively civilized bounds. Rousseau emphasized our most generous and kindly side, which he regarded as the victim of what passes for civilization—the corruptions, and worse, of social and political systems transmitted inexorably through parents to their children. He dismissed the notion of "original sin," and constructed (speculatively, of course) a man of nature who was driven, not by avarice and blind self-interest, but by a powerful and sustaining interest in being with, and responding to, other human beings.

The questions about man's "true" nature may never be solved. But *The Wild Boy of Aveyron*, just published, and *Wolf Children and Feral Man*, made newly available in 1966 (it was first published in 1947), will help us think about what we are, what we might be or might have been, given different external circumstances. The book about the wolf children has as its centerpiece the extraordinary diary of the Reverend J.A.L. Singh, a Christian missionary who ran an orphanage in Midnapore, India. In 1920 the Reverend came upon two children, a girl of about eight and one of about a year and a half, who had evidently been abandoned by their parents and picked up, nurtured, and protected by a mother wolf. The latter was killed, the "human" children captured and brought to the orphanage. Within a year the younger child, Amala, was dead, but Kamala, the older one, lived with the Singhs for nine years. From the beginning the Reverend kept careful notes of what he and his wife went through as they struggled to make human beings out of these wolflike creatures.

The diary is exceedingly moving

by Robert Coles

and informative—recording the patience and devotion of two Christians who will never, it seems, turn their backs on their fellow human beings, however strange or grotesque. The diarist unself-consciously refers to the mother wolf as one "whose nature was so ferocious and affection so sublime," thereby introducing yet another ambiguity and paradox for us—as if the "nature" of man isn't enough of a problem, what is a wolf "really" like? In any event, one wolf nurtured two children, and as Robert Zingg writes (he is the American anthropologist who provides extensive commentary on the Singh diary as well as an analysis of other, similar reported instances of "feral man"), the Reverend Singh has given us "the only completely authentic account" of such a phenomenon. (Feral, or wild, man refers to human beings abandoned as infants and presumably suckled by animals or isolated, for one reason or another, when somewhat older—say at two or three—and compelled to survive in a state of nature, without human support, on their own instinctive or "animallike" cunning and resources.)

The Reverend Singh makes a convincing case for the capacity of two girls to become like wolves in every way imaginable. They cowered and lunged. They scratched and bared their teeth. They ran on all fours. (Teaching them to walk upright was a major problem; Amala died too soon, but Kamala eventually did walk.) They kept to themselves; wanted to hide by day, prowl by night. They were confined, naturally, but treated with respect and affection. They seemed curiously without emotion—merely hungry or sated, on the hunt or resting. They demonstrated no control over their bodily functions and for a long while no positive inter-

Amala and Kamala slept with their bodies entwined.

Photographs from *Wolf Children and Feral Man*, by J.A.L. Singh and Robert M. Zingg

est in other people. But after a year, when young Amala died, we learn that Kamala "shed tears—a drop from each eye." And no question, the girls rather quickly learned to go to Mrs. Singh for food and water, even as the dogs did.

The diarist mingles careful observation of behavior with psychological speculation, philosophical discussion, and religious declaration. He is a confirmed Christian idealist, unquestioning in his loyalty to Christ, and anxious to please him by responding to one of his creatures. He believed that through "the agency of affection" he and his wife would bring about "the desired change"—nothing less than the emergence of Kamala's essential humanity. And in time that is what happened. She began to eat not only raw meat, but biscuits and cake. She learned, painfully, to walk. She acquired speech. But only over a span of years and, as the diary shows, with a certain reluctance. Unfortunately, she died just as she was beginning, really, to be human. The diarist estimates her to have been three or four years old psychologically, although sixteen or so physically, at the time of her death.

At the end of his diary the Reverend Singh briefly but pointedly asks questions that generations of philosophers, psychologists, and anthropologists have put to themselves. How much of our behavior is acquired, how much transmitted genetically? How socialized are we by virtue of who or what we are and how much in response to the molding press of others, who bear down with commands and enticements, thereby making us "human"? For the diarist there is no definitive answer. He leaves it to his readers "to decide between the two factors in human affairs, heredity and the influence of environment." But in fact he has helped his readers enormously with a last note—that "Kamala became a new person in the year 1928"—and indeed with all his notes, which faithfully document that assertion. The dogs he and his wife owned had never learned to stand, to walk, to give names to people, places, things, or to talk. In contrast, Kamala died a human being, after having lived for years with wolves, as a wolflike creature, one might say. Her early life bears witness to the extraordinary range of human adaptation, as does, actually, her later life, too. And obviously it is never a completely clear-cut picture that life presents: heredity *or* the environment.

Our neurological inheritance, as Professor Zingg points out, is structurally unique. It will take generations for the human brain's neurophysiological function to be elucidated, but its singular capacities are observable, and if some of them have been found in the possession of other species, a particular combination of them is, for better or worse, ours: a level of intelligence, the capacity to categorize, name, speak, and so on. Yet, we need one another in order to become human. Isolated at birth from our fellow human beings we die or in some cases grow up feral. Isolated later on, we begin to disintegrate, unless we are old enough to have our essential humanity securely within ourselves. It is true, as Rousseau kept insisting, that the environment radically influences us: we comply, yield, respond, until we "are" what it has asked us to become. But the dogs Kamala associated with so tenaciously for months and months, however affectionately treated by the Singhs, never began to turn human. And Rousseau himself, were he alive today and given everything in the way of a laboratory, even (let us speculate) a cooperative social community, could not enable a dog or a wolf to speak or display the kind of rational, analytic faculty Kamala was clearly developing in the months before her unfortunate death.

When restless, Kamala scratched at the door to get out.

In his long discussion that follows the Singh diary, Professor Zingg makes mention, among other cases, of the wild boy of Aveyron, a lad of about seventeen who was pulled out of a tree by hunters in France. The year was 1799, and the French Revolution was in full sway. Rousseau's insistence that we can be just about anything, depending upon the world we belong to, was exactly what French political leaders were saying: the poor can be liberated, the rich eliminated, and somehow a stable and just world decisively achieved. Soon mobs were running amok, and Edmund Burke from across the channel was understandably, in terror, calling upon Hobbes: exactly what is man but a demonic brute, given the opportunity to reveal his true colors? The wild boy of Aveyron certainly seemed to be a brute—an agitated, impulsive lad who was attached to no one, who ate nuts and berries, shunned or acted indifferent to those who had captured him, and seemed intent only on obtaining food, running about, resting—then seeking more food. "The only blessings he knows in the universe are nourishment, rest, and independence," observed Pierre-Joseph Bonnaterre in his "Historical Notice on the Sauvage de l'Aveyron," published in 1800.

It was not a time when such a youth was likely to be ignored—or condemned outright as a heathen and messenger of the Antichrist. For a number of years French writers and philosophers (not only Rousseau, but Montesquieu, Voltaire, Diderot, and Condillac) had been speculating about so-called primitive man—what we once were and still might be, *if*.

In this book, just published in early 1976, Harlan Lane does an engaging and at times compelling job of bringing the reader back in time to revolutionary France, when so much was being questioned. He uses original documents, historical accounts, later scientific writings, and not least, his own capacity as a first-rate narrator to tell us what the wild boy was like (his actions, the reactions of others to him), and just as important, what he prompted various psychological and educational theorists—psychiatrists like Philippe Pinel or, later, physicians like Maria Montessori—to make of man's possibilities or limitations.

The author is not afraid to use the

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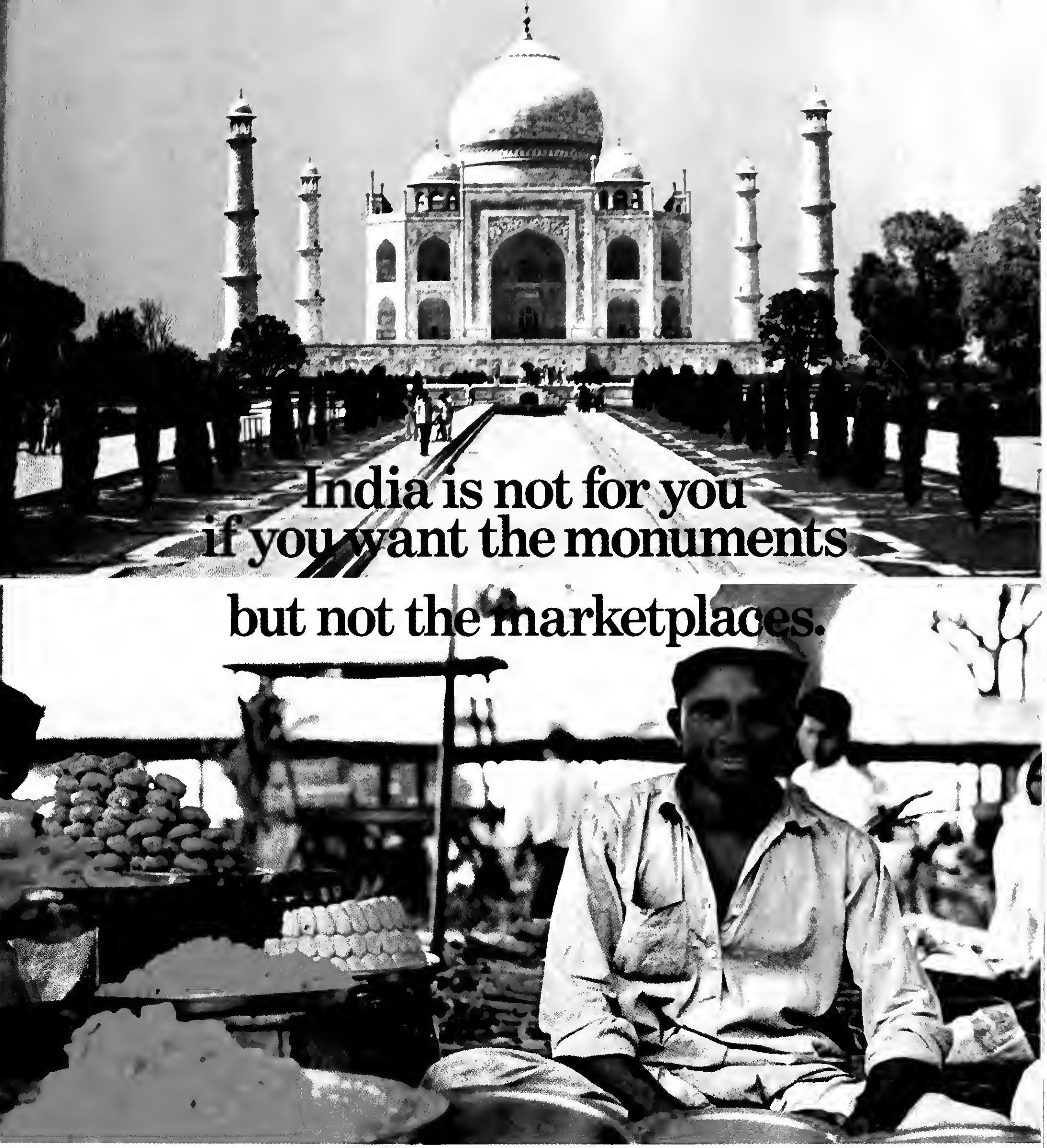
Kamala ate by lapping at food set on the ground.

present tense, is not afraid to tell about his intellectual and even personal hurdles as he went back in time, trying to recapture a drama of sorts—the confrontation between a boy, immediately written off by various authorities as an incurable idiot, and a young, idealistic doctor, Jean-Marc-Gaspard Itard. The doctor was determined to show that a boy with the canniness and adaptiveness to survive what was believed to be years of forest life, was not to be dismissed out of hand by the categorical imperatives, as they could be called, of a given and prevailing classificatory system. Eventually the "boy" (he died at forty) lost his animallike behavior, although he only learned a word or two. Eventually, too, Itard's enthusiasm and hopefulness waned. The wild boy became tame, died, leaving behind a chain of arguments about the level of his intelligence, the value of the rehabilitative efforts made with him, and again and always, the *ifs*. Perhaps a modern-day Itard could have done more. Perhaps intelligence of the kind the boy possessed is not the kind of intelligence our tests measure (and there are millions who, in a way, share his fate, struggling in the jungles of our ghettoes and called by various experts "uneducable" or worse). One wonders how that loving, warm, almost infinitely accepting Mrs. Singh, with her massages and exquisite tenderness, would have done with the wild boy.

In any event, it will not do to romanticize him or to construct ambitious theories based on feral children; they are too few, and each is in many ways idiosyncratic, both as to experience before and after capture. But books such as these two, directed toward an examination of concrete, particular events (hence, in the broadest sense, clinical in orientation) provide interesting, speculative nourishment for all of us who continue to wonder what it is that sets off man from the others who live on this earth, those who, although they possess an assortment of capabilities, do not wonder, self-consciously, about us—the "civilized" ones—whose vast knowledge may destroy all life, including any feral children around and a lot of wild animals, too.

Robert Coles is research psychiatrist for the Harvard University Health Services. At present, he is writing the fourth and fifth volumes of his Pulitzer Prize-winning Children of Crisis.



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An Edible Weed

by Robert H. Mohlenbrock

The scourge of the well-kept lawn is a boon to the salad bowl

The June, 1917, issue of *The Ladies Home Journal* carried an article entitled "In These Days of High Prices: Foods That Cost Us Nothing." Such an article would still be appropriate today, when thousands of Americans are experimenting with and using wild foods in their diet. That early writer included a recipe for dandelion soup, emphasizing that because of its weedy nature, the common dandelion was available to nearly everyone. And not only is the dandelion easily obtained, it is one of the most healthful foods available.

Dandelions have been eaten for centuries, both by volition and as a means of survival. American Indians have relied on the dandelion as a source of food and medicine, referring to it as "strong root." Thomas Green, in his work *Universal Herbal*, published in 1823, gave several uses for the dandelion. He also reported that the citizens of the island of Minorca, east of Spain, once remained alive by eating dandelions (known locally as *camarojas)* after a swarm of locusts had destroyed all other vegetation on the island. During the nineteenth century, the growing and consuming of dandelions were practiced widely in Europe and America. Louis Noisette, in his *Manuel du Jardinier* (1829) gave directions for growing dandelions. (Scarcely anyone today needs help in getting dandelions to grow!) And in 1846, the *Gardeners' Chronicle* of London extolled the virtues of the dandelion as an edible plant.

In 1871, Fearing Burr exhibited four varieties of dandelions at the Massachusetts Horticultural Society: the French large-leaved, the French thick-leaved, the red-seeded, and the American improved. By 1879, French horticulturists were listing five varieties in their catalogs. For some, dandelions became a business. A Mr. Corey, of Brookline, Massachusetts, was reported by *The Massachusetts Horticulture Society Transactions* of 1884 to be growing dandelions from seed for the Boston market.

There are several kinds of dandelions distributed throughout the temperate regions of the world. The most widespread of these, and the one most commonly used for food and drink, is the common dandelion, *Taraxacum officinale*. Other dandelions have similar culinary properties, particularly the red-seeded dandelion.

The dandelion belongs to the huge, diverse family of flowering plants known as the Compositae, a family that includes such other well-known groups as aster, sunflower, goldenrod, and ragweed. The plant is a perennial that produces a long, brownish taproot that may penetrate to a depth of nearly one foot. The very short stem produces a rosette of leaves spread symmetrically around the plant's center. The leaves are generally broadest near the top, tapered toward the base, and coarsely toothed along the margins. The large, jagged teeth caused some early Frenchman to refer to the plant as *dent-de-lion*, or "lion's tooth," a name that, with a little alteration, has become universal. From the center of the rosette of leaves, a single flower-bearing stem, or scape, rises. Hollow throughout, the scape contains a milky sap, or latex.

Dandelions flower mostly during the spring and summer months. The yellow-flowered head, which may attain a diameter of two inches, is actually a cluster of many individual flowers, each represented by a strap-shaped ray. The familiar globose, fruiting cluster develops from the yellow flower head. Each individual yellow-green fruit in the head has an elongated beak terminating in a cluster of delicate white hairs. These hairs, which serve as a parachute, enable the fruit to be wind-dispersed.

Nearly every part of the dandelion is edible. The roots can be baked, ground, and used as a substitute for, or an adulterant of, coffee. The flowers are used to make dandelion wine. Even the tiny fruits are said to have enough nutritive value to be used as a survival food. But it is the leaves that provide for most of the delicacies for the palate. Not only do properly prepared dandelion greens taste good, but they are among the most nutritious of all vegetables, wild or cultivated. Data on the most widely used wild and cultivated green vegetables reveal the dandelion ranks first in vitamin A, vitamin B, carbohydrates, and food energy (calories per 100 grams), and third in proteins, calcium, and phosphorus.

Before use, the leaves should be washed twice in cold water and allowed to drain. If not used immediately, they may be stored in the refrigerator. (Do not collect dandelion leaves that may have been subjected to the herbicide 2,4-D.) Blanching of the leaves removes much of the bitterness, and a good way to obtain blanched leaves is to cover the young dandelion plants with a layer of straw. The very young leaves can be eaten uncooked in salads. A special recipe that my wife has developed is wilted dandelions.

Wilted Dandelions

1 teaspoon salt
¼ teaspoon pepper
½ teaspoon dry mustard
6 tablespoons sugar
1 teaspoon dry, minced onion
1 tablespoon salad oil
⅓ cup vinegar
⅔ cup water
Dandelion greens, washed and chilled
Bacon or ham pieces, fried and drained

1. Tear dandelion greens into bite-sized pieces and place in a large salad bowl.
2. Mix first eight ingredients and pour over greens.

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Bruce Coleman, Inc.

3. Toss the bacon or ham pieces with the greens and serve.

Dandelion leaves also make a delicious potherb. They are prepared in about the same way as spinach. Unless blanched or very young leaves are used, it is wise to boil them in two or three changes of water to remove any bitterness. Care should be taken not to overboil the greens, however, or much of the nutrient value will be lost. Although there are several delicious ways to use dandelion as a potherb, here is one of my favorites.

Dandelion Casserole with Mushrooms

1¼ pounds dandelion leaves, chopped
½ pound mushrooms, washed and dried
1 teaspoon salt
1 teaspoon dry, minced onion, mixed with 1 teaspoon water
2 tablespoons melted butter or margarine
1 cup evaporated milk
1 cup grated American cheese
Garlic salt

1. Boil and drain chopped dandelion leaves twice (add ½ teaspoon salt the second time), and season with salt, onion, and butter (or margarine).
2. Slice off mushroom stems and sauté both caps and stems in butter for several minutes until browned.
3. Line a flat, 8- by 8-inch baking dish with the cooked, seasoned dandelion greens.
4. Arrange mushroom caps and stems over the greens and sprinkle with garlic salt.
5. Prepare sauce by bringing milk to a simmer and adding freshly grated cheese. Cook for 2 to 3 minutes, then let stand for about 5 minutes. Carefully spoon sauce over ingredients in baking dish.
6. Bake at 350° for 30 minutes.

Although human consumption is an important use for the dandelion, several other virtues are known. Deer, rabbits, and other wildlife use the dandelion for forage. Dandelion leaves are said to be used as food by silkworms when mulberry leaves are not available. And the roots of a Russian species produce latex that has been used commercially in the USSR since about 1931. Although several medicinal properties are also attributed to the dandelion—from a cure for dyspepsia to one for a torpid liver—I will not prescribe any medicinal use for dandelion for fear of being accused of malpractice.

Robert H. Mohlenbrock is department chairman and professor of botany at Southern Illinois University.

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Calcutta, India

Radha Kanta Paul

Announcements

The Alvin Ailey Repertory Workshop will present a one-hour program in the Auditorium of The American Museum of Natural History on Sunday, April 11, at 2:00 P.M. Excerpts from "Revelations" will be included.

Trout Flies opens April 1 in the Roosevelt Memorial Hall, 2nd floor of the Museum. This extraordinary collection combines historic and contemporary examples of the flytiers art with paintings, photographs, etchings, and three-dimensional trout. The Museum Showcase features a framed collection of flies by Frederic M. Halford, the historian of the dry fly; flies by Theodore Gordon, the father of American fly tying; contemporary flies depicting nymphs and wet flies by Ted Niemeyer; studies of the material used by flytiers; and a videotape of fly tying. Fly tying demonstrations are planned for the first two weeks.

Beginning April 20, Farida Wiley will conduct **Field Walks in Natural Sciences** to study bird migration. All-day weekend trips to various habitats for the study of birds, other animals, and plants will start on April 24. For details, call (212) 873-1300, Ext. 345, weekdays only, between 9:00 and 11:30 A.M. or 1:00 and 4:00 P.M.

The Department of Education's African-American Studies Group will present the **African Lecture Series**—three lectures dealing with Africa and people of African descent. The first will be held in the Museum's Auditorium on Wednesday, April 28, at 7:30 P.M.

Reservations are still being accepted for the **East African Geological Safari** in August. Visits will be made to the major game parks and reserves in Kenya and Tanzania, as well as to mines, volcanoes, the famed Rift Valley, and other sites of geologic significance off the beaten track. A day will be spent in the company of Dr. Mary Leakey at Olduvai Gorge. Christopher J. Schuberth, lecturer in geology at the Museum and adjunct professor of geology at the City University of New York, will conduct the tour. For a descriptive brochure, write or call the Museum's Department of Education (212) 873-7507.

At the **Hayden Planetarium** of the Museum, "The Final Frontier" continues through April 5. This Sky Show takes us on a futuristic voyage to the outer reaches of space aboard the nuclear-propelled spacecraft *Eratosthenes*. A new Sky Show, "Things That Go Beep in the Night," begins April 7. The invention of radio astronomy in the 1930s opened a new window to the universe, enabling astronomers to "listen in" on distant galaxies, exploding stars, pulsating stars, quasars, and black holes. Shows begin at 2:00 P.M. and 3:30 P.M. on weekdays, with more frequent showings on weekends. Admission is $2.35 for adults; $1.35 for children.

Eco-Visions—An environmental film series presented by the Environmental Information Center of the Museum, can be seen from 1:30 to 3:00 P.M. on Thursday afternoons in the Education Hall, and at 2:00 and 3:00 P.M. on Saturdays in the People Center. This series will continue through April and May. For details on film subjects call 873-1300, Ext. 527, from 10:30 A.M. to noon Tuesday through Friday.

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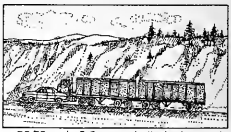

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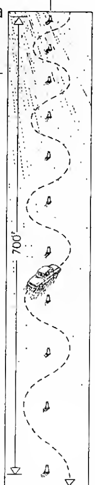

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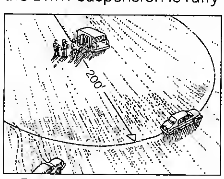

Results of the Motor Trend "200 Ft. Circle Test" clearly illustrate the superior road holding abilities of the BMW. At .82g BMW was still on the road, other makes were not

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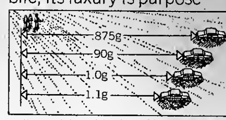

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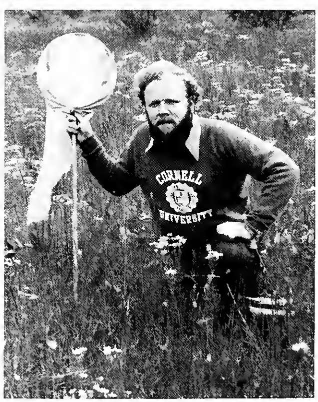
Cover: *Crystalline sulfur, from Girgenti, Sicily, shows the variation possible in the external appearance of this mineral. The specimen on the cover (2″ wide x 3″ high x 3″ deep), as well as the minerals illustrated in the story on page 38, will be on display in the new Hall of Minerals and Gems of The American Museum of Natural History, opening on May 21. Photograph by Henry Janson.*

Authors

Several years ago, **William A. Calder III** was standing under a tree in Jackson Hole, Wyoming, when a calliope hummingbird flew to its nest in the branches above. Calder wondered how the tiny bird maintained its body temperature during the freezing nights. His curiosity led to his present research on hummingbird thermoregulation. For the past seven years, Calder, who teaches zoology at the University of Arizona, has studied the way an animal's body size influences its physiology and habitat requirements (*see* "There Really is a Roadrunner," *Natural History*, April 1968). The work, which involves the use of recording equipment, is often frustrating because of frequent mechanical breakdowns. A calming effect, Calder finds, is to strum classical or ragtime music on a mandolin he always takes with him into the field.

Born and educated in England, **Kenneth Hewitt** first visited the mountainous Indus Kohistan region of Pakistan in 1961 as a consultant on the natural hazards that affect water development. He returned last year to study the effects on that precarious environment of the 1974 earthquake. He has done disaster appraisal for the Canadian Emergency Measures Organization and has served as an adviser to UNESCO's Disaster Division and its Man and Biosphere Program. Hewitt taught at the University of Toronto for seven years before coming to the Department of Human Ecology at Cook College, Rutgers University, in 1973.



Editor of the publications of the Northeastern Field Naturalists' Society, **Frederick C. Schlauch** conducted research on the reptiles of his native Long Island long before he began formal university study. At present a graduate student in the ecology program at Rutgers University, Schlauch received his B.S. from Cornell University. In addition to his work on the effects of urbanization on Long Island's amphibians and reptiles, he is also pursuing studies on the plant communities of the endangered Long Island Pine Barrens and on the general biogeography of the Atlantic Coastal Plain of northeastern United States.

Leonard Radinsky traces his interest in brain evolution to the chance reading of a journal article in which he learned that the raccoon's brain anatomy reflects its sensitive hands. Realizing that brain mapping could be used to indicate the specialized behaviors of extinct animals, he has made and studied nearly a thousand casts of the braincases of living and fossil species. A vertebrate paleontologist in the Department of Anatomy at the University of Chicago, Radinsky hopes to explore the fossil record of ungulate and carnivore brains to learn how changes in one group affected the other. **Douglas Cramer,** whose drawings accompany Radinsky's article, teaches physical anthropology at Rutgers University, anatomy at New York University Medical School, and is a medical and biological illustrator.

 by Richard M. Klein

Maypoles and Earth Mothers

Our innocent rites of spring have ancient and carnal antecedents

On the first of May, the might of the Soviet army is paraded through Red Square in Moscow, and union leaders in other industrialized nations extol the grandeur and nobility of the working man and woman. Until at least partway through this century, yet another ceremony marked the day in many countries: the Maypole dance, in which young girls crowned with flowers and wearing frilly dresses danced around a tall pole hung with ribbons. The Maypole dance was a happy, innocent amusement, a symbol of joy in spring's arrival, as evidenced by a softness in the air, delicate light-green leaves, and the blooming of flowers. Few recognize that the Maypole and its dance are among the oldest and most sexual of public ceremonies.

A search for the origin of the Maypole tradition starts in the Fertile Crescent, the historic region that has now become the troubled Middle East. The crescent includes parts of today's Syria, Lebanon, Israel, Jordan, Iraq, and Iran. In spite of differences in the cultures of the tribes that lived there four to six millennia ago, those ancient peoples had several things in common, among which was an Earth Mother goddess and a tree sacred to her.


Alexa Grace

In many cultures, trees were considered the place where man originated and a particular species of tree was accordingly the abode of a god. It was to the Earth Mother, whatever her local tribal name, that the tribespeople prayed for good crops and for impregnation of the women and the herds. And it was to her that pleas for intercession with the male gods partnered with her were made for rain, gentle breezes, and pure, everflowing springs. The fructification of the Earth Mother was another duty of the principal male god, for if the goddess was with child, it was believed that the fields, the women, and the ewes would also be fruitful. When the Earth Mother was pregnant, the manifestation of her divine powers was demonstrated by the seeming resurrection of the trees, barren throughout the long dry season. The faith of individuals, as well as tribes, rested in some measure on the cyclical recurrence of these manifestations.

But such miracles could not be left to mere whim. Lest they forget, the gods needed to be appeased and annually reminded of their responsibilities to the faithful; the people likewise needed to be reminded of their duty to the gods. In one such ceremony, Cybele, an Earth Mother of ancient Asia Minor, was symbolized by a palm or cedar tree, shorn of all but its topmost branches and fronds, that was carried in solemn procession to the temple and erected there before the gaze of the multitude. Decked with flowers, the tree was ritually worshiped with dances that included what modern comparative re-

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ligionists refer to, without supplying details, as orgies culminating in blood sacrifices. Similar spring rites involving an Earth Mother figure and a symbolic stripped tree were observed throughout the Fertile Crescent and as far afield as Crete and India.

The deities of the Fertile Crescent were probably transported by conquering tribes to mainland Greece, where their names were changed, they were blended with the local pantheon, and they were made more "human," accessible, and understandable. Cybele, for example, probably evolved into Artemis, the goddess of wild animals, the hunt, vegetation, chastity, and childbirth; her cult involved the dancing of tree nymphs. Although we know little about the spring fertility rituals of the various city-states of classical Greece, surviving sculptures and wall paintings indicate that the pole-dance-orgy complex was retained with modifications derived from Egypt via Crete and Cyprus.

With the Roman hegemony over the Mediterranean, regional gods and goddesses and their functions were largely maintained but they became identified with the deities of the conquerors. Rituals broadened as armies acquired new gods in their travels, and once again the deities' names were changed. The Earth Mother Cybele-Artemis, for instance, became associated with the Roman goddess Diana. Claudius, emperor during the struggles with Hannibal about 200 B.C., chose Cybele as the official Earth Mother and reactivated her spring rituals, but most of the populace preferred the local goddess Diana, huntress and protector of women, who eased the pain of childbirth and was supposed to be a favorite of Jupiter.

The pagan spring ritual began in Rome on the twenty-second of March when a pine tree was cut down and debranched by acolytes of Diana's priests and borne to her temples by designated tree bearers. The tree shaft was decked with violets as the spiritual manifestation of the male god Attis—mythical consort of the Earth Mother—and was erected with due ceremony. The twenty-third of March, called the Day of Blood, started with dancing around the symbolic tree shaft to the music of cymbals, drums, and flutes, which became wilder as evening came on. Frenzied by the dance, and possibly by plant hallucinogens, the participants lacerated themselves and dripped their blood on statues of Diana. This orgiastic dance culminated in the ritualistic, but nonetheless actual, self-emasculation of young men wishing to become the goddess's priests. The excised organs were thrown at the tree to hasten the reawakening of the earth, as in the rituals practiced centuries before by the followers of Artemis and Cybele.

The twenty-fifth of March was called the Festival of Joy by the Romans and included more dancing and masques that foreshadowed the contemporary Mardi Gras. The next day was, happily, a day of rest and was followed on the twenty-seventh of March by a procession led by stand-ins for Diana and her male consort, the King of the Woods, who was most often the chief priest of Diana's sacred grove. That night the ceremony concluded with the ritual mating of the King of the Woods with the goddess and a general orgy—again never spelled out in detail.

The King of the Woods was originally the fructifying, impregnating agent. He, too, had different names at different times—Attis in his earliest manifestation, Zeus to the Greeks, Jupiter to the Romans—and he, too, was symbolized by a tree, frequently a forest giant such as an oak or an ash. In most cultures, the King of the Woods was figuratively slain or a human stand-in was literally killed at the end of the mating ceremony so that he could be reborn—resurrected—as a further revelation of the rebirth of spring.

When Christianity extended its sway outward from Rome, the spring festival, which had spread north from the city and westward from the Middle East, became a source of concern to the young church, still unsure of its sway over believers only recently wrenched from paganism. The Maypole was accordingly suppressed, insofar as the priests could root out beliefs so deeply implanted in the mind. Yet, the Dark Ages and the Middle Ages in Europe were periods when faith in something, in *anything,* was necessary. No cautious peasant was

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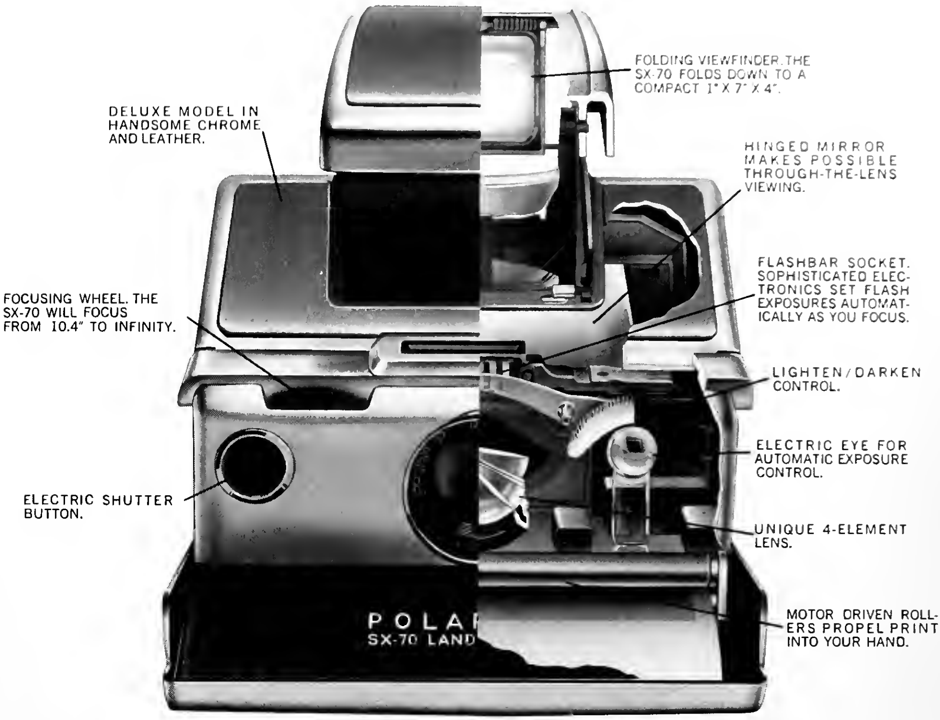

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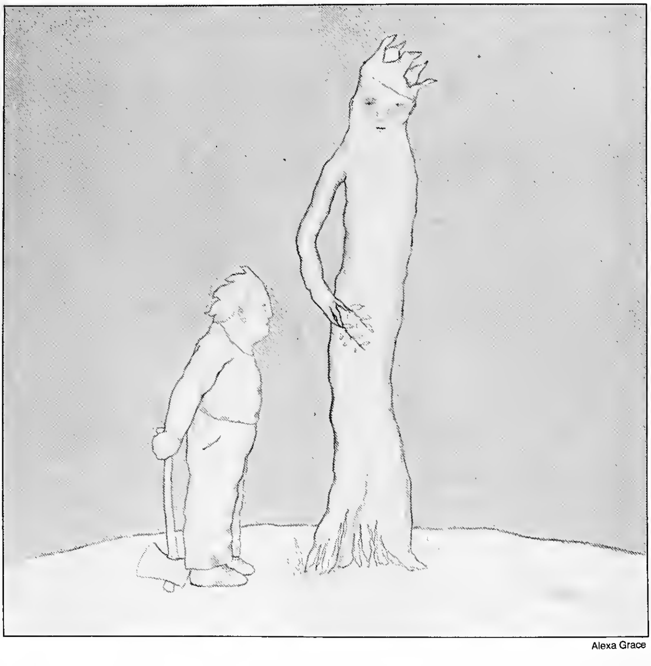
going to discard a ritual that could not hurt his crops and just might help, and it mattered little whether the spring planting was sanctified by invoking a Christian symbol or the Earth Mother as manifested by a branchless tree.

The Maypole ceremony with its ritual mating was thus solemnized throughout Europe, falling variously within a few weeks of the time of sowing. By about the tenth century, the ceremony was observed in most of Europe on the first of May. But that was not always the date of the spring ritual. Whitsunday, the seventh Sunday and fiftieth day after Easter, was celebrated in the Balkans; Saint George's Day, the twenty-third of April, was the holiday in Poland and Russia; and in the north, where spring comes late, Midsummer Day, June 24, was chosen.

By the time of the Dark Ages, the spring ritual, with minor variations, was similar throughout Europe. Young men and women went into the woods at midnight, cut down a tree, stripped off its branches, and carried the Maypole triumphantly back to their village in the morning. The pole was decorated—with flowers, sheaves of the previous harvest, and other symbols of fruitfulness—and to the discomfiture of the clergy, was set up in the commons or in front of the church. A May Queen and a King of the Woods were selected to preside over the dancing.

In Saxony and Prussia, the Maypole of the Slavic Wends was surmounted with an iron cock, the pole was greased, and boys climbed it to pluck sausages and eggs from the top. As night came, the queen and king (and many other couples) mated in the fields to drive home the point of the ceremony, and a fair number of children were born the next January. An effigy of the King of the Woods was then burned or thrown in the local river, if there was one, to the chant of "We are carrying death out, we are bringing dear summer back."

The Celts of Scotland, Ireland, Normandy, and parts of Scandinavia included a fire ceremony in their May Day ritual. Ceremonial fires were lit on hilltops from a flame started with a bow and spindle of oak fitted into the slot of a board of a softer wood such as willow. The tinder was dried mushrooms and puffballs. In Sweden, the Maypole, or Maj Stäng, is still constructed with a series of crosspieces from which hoops of willow bound round with flowers are hung. Garlanded hoops were also rolled. The hoop rolling practiced on May Day at some of our private eastern women's colleges derives from these garlanded Scandinavian hoops. But there is one significant difference: in olden times, the oaken hoop stick was thrown through the hoop instead of being used to propel it—a symptom perhaps of the general bowdlerizing of May Day rituals.


Alexa Grace

It is to England that we must look for our North American version of the May Day ceremony. From the tenth to the sixteenth century, the mating of the May Queen and the King of the Woods was not just symbolic, and the midnight cutting of the tree was accompanied by the normal exuberance of lusty youths without supervision. The prominent English Puritan pamphleteer Philip Stubbes, in his *Anatomie of Abuses* of 1583, called the whole ritual an "act of Sathan," referred to the Maypole itself as "that stynking ydol," and noted that after the night's revels, "scarsely the thirde part of the girls returned undefiled."

A freewheeling anti-Puritan American colonist, Thomas Morton, created a scandal by introducing the Maypole to New England in 1626 when he became administrator of a settlement near the Plymouth Colony. The governor of the main colony noted that the celebrants invited Indian women to participate in "dancing and frisking together . . . and worse." The Pilgrims knew quite well what the Maypole was all about, even though they predated Freud.

By the beginning of the seventeenth century, however, most of the May Day celebration had been sanitized in England, and North America shortly followed suit. May Day was no longer to be an excuse for sexual license. The celebration was just that: a celebration, not a ritual. By 1832, Tennyson could write a pastoral poem called "The May Queen," and pre-Victorian novelists could include descriptions of Maypoles and Morris dances, whose origins probably went back to the orgiastic pagan rituals of the Fertile Crescent, without offending Anglican sensibilities. Victorian sniggerings were encouraged by Kipling's doggerel, "Oh do not tell the priest our plight or he would call it sin / But we have been out in the woods all night conjuring summer in." The lusty Earth Mothers and May Queens of yore have become today's scrubbed-up local Miss Americas.

Oh Cybele, how the mighty have fallen!

Richard M. Klein teaches botany at the University of Vermont.

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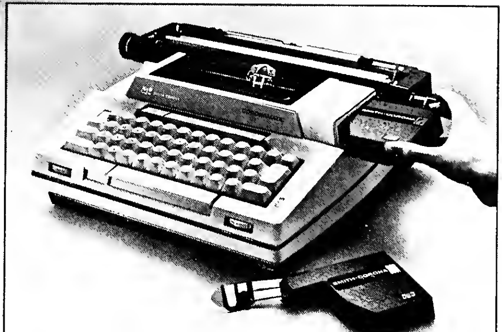

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Biological Potential vs. Biological Determinism

Because of its social and political implications, the debate about determinism continues

In 1758, Linnaeus faced the difficult decision of how to classify his own species in the definitive edition of his *Systema Naturae.* Would he simply rank man among the other animals or would he create for us a separate status? Linnaeus compromised. He placed us within his classification (close to monkeys and bats), but set us apart by his description. He defined our relatives by the mundane, distinguishing characters of size, shape, and number of fingers and toes. For *Homo sapiens,* he wrote only the Socratic injunction: *nosce te ipsum*—"know thyself."

For Linnaeus, *Homo sapiens* was both special and not special. Unfortunately, this eminently sensible resolution has been polarized and utterly distorted by most later commentators. Special and not special have come to mean nonbiological and biological, or nurture and nature. These later polarizations are nonsensical. Humans are animals and everything we do lies within our biological potential. Nothing arouses this ardent (although currently displaced) New Yorker to greater anger than the claims of some self-styled "eco-activists" that large cities are the "unnatural" harbingers of our impending destruction. But—and here comes the biggest *but* I can muster—the statement that humans are animals does not imply that our specific patterns of behavior and social arrangements are in any way directly determined by our genes. *Potential* and *determination* are different concepts.

The intense discussion aroused by E.O. Wilson's *Sociobiology* has led me to take up this subject. Wilson's book has been greeted by a chorus of praise and publicity (for example, the review by R.S. Morison in the November 1975 issue of *Natural History*). I, however, find myself among the smaller group of its detractors. Most of *Sociobiology* wins from me the same high praise almost universally accorded to it. For a lucid account of evolutionary principles and an indefatigably thorough discussion of social behavior among all groups of animals, *Sociobiology* will be the primary document for years to come. But Wilson's last chapter, "From Sociobiology to Sociology," leaves me very unhappy indeed. After twenty-six chapters of careful documentation for the nonhuman animals, Wilson concludes with an extended speculation on the genetic basis of supposedly universal patterns of human behavior. Unfortunately, since this chapter is his statement on human behavior, it has also attracted more than 80 percent of all the commentary in the popular press.

We who have criticized this last chapter have been accused of denying altogether the relevance of biology to human behavior, of reviving an ancient superstition by placing man outside the rest of "the creation." Are we pure "nurturists?" Do we permit a political vision of human perfectibility to blind us to evident constraints imposed by our biological nature? The answer to both is no. The issue is not universal biology vs. human uniqueness, but biological potentiality vs. biological determinism.

Replying to a critic of his article in the *New York Times Magazine* (Oc-

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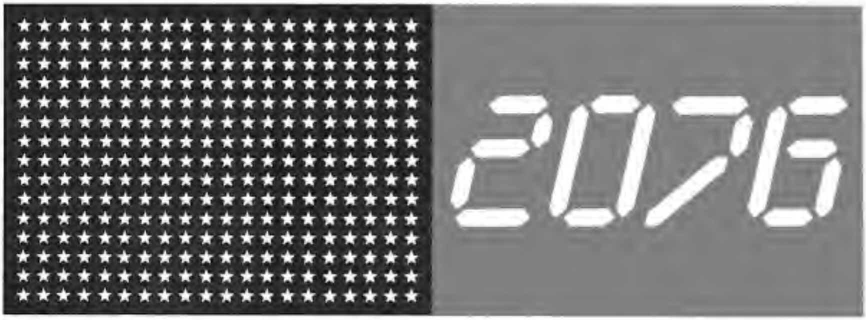

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tober 12, 1975), Wilson wrote:

> There is no doubt that the patterns of human social behavior, including altruistic behavior, are under genetic control, in the sense that they represent a restricted subset of possible patterns that are very different from the patterns of termites, chimpanzees and other animal species.

If this is all that Wilson means by genetic control, then we can scarcely disagree. Surely we do not do all the things that other animals do, and just as surely, the range of our potential behavior is circumscribed by our biology. We would lead very different social lives if we photosynthesized (no agriculture, gathering, or hunting—the major determinants of our social evolution) or had life cycles like those of certain gall midges. (When feeding on an uncrowded mushroom, these insects reproduce in the larval or pupal stage. The young grow within the mother's body, devour her from inside, and emerge from her depleted external shell ready to feed, grow the next generation, and make the supreme sacrifice.)

But Wilson makes much stronger claims. Chapter 27 is not a statement about the range of potential human behaviors or even an argument for the restriction of that range from a much larger total domain among all animals. It is, primarily, an extended speculation on the existence of genes for specific and variable traits in human behavior—including spite, aggression, xenophobia, conformity, homosexuality, and the characteristic behavioral differences between men and women in Western society. Of course, Wilson does not deny the role of nongenetic learning in human behavior; he even states at one point that "genes have given away most of their sovereignty." But he quickly adds, genes "maintain a certain amount of influence in at least the behavioral qualities that underlie variations between cultures." And the next paragraph calls for "a discipline of anthropological genetics."

Linnaeus in Lapland attire

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Biological determinism is the primary theme in Wilson's discussion of human behavior; chapter 27 makes no sense in any other context. Wilson's primary aim, as I read him, is to suggest that Darwinian theory might reformulate the human sciences just as it has succeeded so spectacularly in other biological disciplines. But Darwinian processes cannot operate without genes to select. Unless the "interesting" properties of human behavior are under specific genetic control, sociology need fear no invasion of its turf. By interesting, I refer to the subjects sociologists and anthropologists fight about most often—aggression, social stratification, and differences in behavior between men and women. If genes only specify that we are large enough to live in a world of gravitational forces, need to rest our bodies by sleeping, and do not photosynthesize, then the realm of genetic determinism will be relatively uninspiring.

What is the direct evidence for genetic control of specific human social behavior? At the moment, the answer is none whatever. (It would not be impossible, in theory, to gain such evidence by standard, controlled experiments in breeding, but we do not raise people in *Drosophila* bottles, establish pure lines, or control environments for invariant nurturing.) Sociobiologists must therefore advance indirect arguments based on plausibility. Wilson uses three major strategies: universality, continuity, and adaptiveness.

1. Universality: If certain behaviors are invariably found in our closest primate relatives and among humans themselves, a circumstantial case for common, inherited genetic control may be advanced. Chapter 27 abounds with statements about supposed human universals. For example, "Human beings are absurdly easy to indoctrinate—they *seek* it." Or, "Men would rather believe than know." I can only say that my own experience does not correspond with Wilson's.

When Wilson must acknowledge diversity, he often dismisses the uncomfortable "exceptions" as temporary and unimportant aberrations. Since Wilson believes that repeated, often genocidal warfare has shaped our genetic destiny, the existence of nonaggressive peoples is embarrassing. But he writes: "It is to be expected that some isolated cultures will escape the process for generations at a time, in effect reverting temporarily to what ethnographers classify as a pacific state."

In any case, even if we can compile a list of behavioral traits shared by humans and our closest primate relatives, this does not make a good case for common genetic control. Similar results need not imply similar causes; in fact, evolutionists are so keenly aware of this problem that they have developed a terminology to express it. Similar features due to common genetic ancestry are "homologous"; similarities due to common function, but with different evolutionary histories, are "analogous" (the wings of birds and insects, for example—the common ancestor of both groups lacked wings). I will argue below that a basic feature of human biology supports the idea that many behavioral similarities between humans and other primates are analogous, and that they have no direct genetic specification in humans.

2. Continuity: Wilson claims, with ample justice in my opinion, that the Darwinian explanation of altruism in W.D. Hamilton's 1964 theory of

"kin selection" forms the basis for an evolutionary theory of animal societies. Altruistic acts are the cement of stable societies, yet they seem to defy a Darwinian explanation. On Darwinian principles, all individuals are selected to maximize their own genetic contributions to future generations. How, then, can they willingly sacrifice or endanger themselves by performing altruistic acts to benefit others?

The resolution is charmingly simple in concept, although complex in technical detail. By benefiting relatives, altruistic acts preserve an altruist's genes even if the altruist himself will not be the one to perpetuate them. For example, in most sexually reproducing organisms, an individual shares an average of half the genes of his sibs and one-eighth the genes of his first cousins. Hence, if faced with a choice of saving oneself alone or sacrificing oneself to save more than two sibs or more than eight first cousins, the Darwinian calculus favors altruistic sacrifice, for in so doing, an altruist actually increases his own genetic representation in future generations.

Natural selection will favor the preservation of such self-serving altruist genes. But what of altruistic acts toward nonrelatives? Here sociobiologists must invoke a related concept of "reciprocal altruism" to preserve a genetic explanation. The altruistic act entails some danger and no immediate benefit, but if it inspires a reciprocal act by the current beneficiary at some future time, it may pay off in the long run: a genetic incarnation of the age-old adage, You scratch my back and I'll scratch yours (even if we're not related).

The argument from continuity then proceeds. Altruistic acts in other animal societies can be plausibly explained as examples of Darwinian kin selection. Humans perform altruistic acts and these are likely to have a similarly direct genetic basis. But again, similarity of result does not imply identity of cause (see below for an alternate explanation based on biological potentiality rather than biological determinism).

3. Adaptiveness: Adaptation is the hallmark of Darwinian processes. Natural selection operates continuously and relentlessly to fit organisms to their environments. Disadvantageous social structures, like poorly designed morphological structures, will not survive for long.

Human social practices are clearly adaptive. One of my predecessors in these columns, anthropologist Marvin Harris, has delighted in demonstrating the logic and sensibility of those social practices in other cultures that seem most bizarre to smug Westerners (*Cows, Pigs, Wars, and Witches,* Random House, 1974). Human social behavior is riddled with altruism; it is also clearly adaptive. Is this not a prima facie argument for direct genetic control? My answer is definitely "no," and I can best illustrate my claim by reporting an argument I had with a colleague, an eminent anthropologist.

My colleague insisted that the classic story of Eskimo on ice floes provides adequate proof for the existence of specific altruist genes maintained by kin selection. Apparently, among some Eskimo peoples, social units are arranged as family groups. If food resources dwindle and the family must move to survive, aged grandparents willingly remain behind (to die) rather than endanger the survival of the entire family by slowing an arduous and dangerous migration. Family groups with no altruist genes have succumbed to natural selection as migrations hindered by the old and sick lead to the death of entire families. Grandparents with altruist genes increase their own fitness by their sacrifice, for they insure the survival of close relatives sharing their genes.

The explanation by my colleague is plausible, to be sure, but scarcely conclusive since an eminently simple, nongenetic explanation also exists: there are no altruist genes at all, in fact, no important genetic differences among Eskimo families whatsoever. The sacrifice of grandparents is an adaptive, but nongenetic, cultural trait. Families with no tradition for sacrifice do not survive for many generations. In other families, sacrifice is celebrated in song and story; aged grandparents who stay behind become the greatest heroes of the clan. Children are socialized from their earliest memories to the glory and honor of such sacrifice.

I cannot prove my scenario, any more than my colleague can demonstrate his. But in the current context of no evidence, they are at least equally plausible. Likewise, reciprocal altruism undeniably exists in human societies, but this provides no evidence whatever for its genetic basis. As Benjamin Franklin said: "We must all hang together, or assuredly we shall all hang separately." Functioning societies may require reciprocal altruism. But these acts need not be coded into our being by genes; they may be inculcated equally well by learning.

I return, then, to Linnaeus's compromise that we are both ordinary and unique. The central feature of our biological uniqueness also provides the major reason for doubting that our behaviors are directly coded by specific genes. That feature is, of course, our large brain. Size itself is a major determinant of the function and structure of any object. The large and the small cannot work in the same way. We know best the structural changes that compensate for the decrease of surface area in relation to volume of large creatures, for example, thick legs and convoluted internal surfaces such as lungs and villi of the small intestine. But markedly increased brain size in human evolution may have had the most profound consequences of all. The increase added enough neural connections to convert an inflexible and rigidly programmed device into a labile organ. Endowed with sufficient logic and memory, the brain may have substituted nonprogrammed learning for direct specification as the ground of social behavior. Flexibility may well be the most important determinant of human consciousness; the direct programming of behavior has probably become inadaptive.

Why imagine that specific genes for aggression, dominance, or spite have any importance when we know that the brain's enormous flexibility permits us to be aggressive or peaceful, dominant or submissive, spiteful or generous? Violence, sexism, and general nastiness *are* biological since they represent one subset of a possible range of behaviors. But peacefulness, equality, and kindness are just as biological—and we may see their influence increase if we can create social structures that permit them to flourish. Thus, my criticism of Wilson does not invoke a nonbiological "environmentalism"; it merely pits the concept of biological potentiality, with a brain capable of the full range of human behaviors and predisposed toward none, against the idea of biological determinism, with specific genes for specific behavioral traits.

But why is this academic issue so delicate and explosive? There is no hard evidence for either position, and

what difference does it make, for example, whether we conform because conformer genes have been selected or because our general genetic makeup permits conformity as one strategy among many?

The protracted and intense debate surrounding biological determinism has arisen as a function of its social and political message. As I have argued in several columns (April 1974, June-July 1975, March 1976), biological determinism has always been used to defend existing social arrangements as biologically inevitable—from "for ye have the poor always with you" to nineteenth-century imperialism to modern sexism. Why else would a set of ideas so devoid of factual support gain such a consistently good press from established media throughout the centuries? This usage is quite out of the control of individual scientists who propose deterministic theories for a host of reasons, often benevolent.

I make no attribution of motive in Wilson's or anyone else's case. Neither do I reject determinism because I dislike its political usage. Scientific truth, as we understand it, must be our primary criterion. We live with several unpleasant biological truths, death being the most undeniable and ineluctable. If genetic determinism is true, we will learn to live with it as well. But I reiterate my statement that no evidence exists to support it, that the crude versions of past centuries have been conclusively disproved, and that its continued popularity is a function of social prejudice among those who benefit most from the status quo.

But let us not saddle *Sociobiology* with the sins of past determinists. What have been its direct results in the first few months of its excellent publicity? At best, we see the beginnings of a line of social research that promises only absurdity by its refusal to consider immediate nongenetic factors. The January 30, 1976, issue of *Science* (America's leading technical journal for scientists) contains an article on panhandling that I would have accepted as satire if it had appeared verbatim in the *National Lampoon*. The authors dispatched "panhandlers" to request dimes from various "targets." Results are discussed only in the context of kin selection, reciprocal altruism, and the food-sharing habits of chimps and baboons—nothing on current urban realities in America. As one major conclusion, they find that male panhandlers are "far more successful approaching a single female or a pair of females than a male and female together; they were particularly unsuccessful when approaching a single male or two males together." But not a word about urban fear or the politics of sex—just some statements about chimps and the genetics of altruism (although they finally admit that reciprocal altruism probably does not apply—after all, they argue, what future benefit can one expect from a panhandler).

In the first negative comment on *Sociobiology*, economist Paul Samuelson (*Newsweek*, July 7, 1975) urged sociobiologists to tread softly in the zones of race and sex. I see no evidence that his advice is being heeded. In his *New York Times Magazine* article of October 12, 1975, Wilson writes:

> In hunter-gatherer societies, men hunt and women stay at home. This strong bias persists in *most* [my emphasis] agricultural and industrial societies and, on that ground alone, appears to have a genetic origin. . . . My own guess is that the genetic bias is intense enough to cause a substantial division of labor even in the most free and most egalitarian of future societies. . . . Even with identical education and equal access to all professions, men are likely to continue to play a disproportionate role in political life, business and science.

I can only repeat Kate Millett's complaint that "patriarchy has a tenacious or powerful hold through its successful habit of passing itself off as nature."

We are both similar to and different from other animals. In different cultural contexts, emphasis upon one side or the other of this fundamental truth plays a useful social role. In Darwin's day, an assertion of our similarity broke through centuries of harmful superstition. Now we may need to emphasize our difference as flexible animals with a vast range of potential behavior. Our biological nature does not stand in the way of social reform. We are, as Simone de Beauvoir said, "l'être dont l'être est de n'être pas"—the being whose essence lies in having no essence.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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Energy Crisis of the Hummingbird

by William A. Calder III

Survival for this tiny bird often depends upon its ability to regulate metabolism

When European immigrants first began to settle the eastern seaboard of North America, they found many birds similar in appearance to those they had left behind. But they were struck by one species that they had never before seen. In 1714, John Lawson, an Englishman, wrote an account of his travels through what is now North Carolina, and described this unique bird:

> The Humming-Bird is the Miracle of all our winged Animals. He is feathered as a Bird, and gets his Living as the Bees, by sucking the Honey from each Flower. His Nest is one of the greatest pieces of Workmanship the Whole Tribe of winged Animals can show. . . . The Eggs are the Bigness of Pease.

In those days, the study of biology primarily encompassed cataloging the physical characteristics and habits of organisms, and body size, in extremes, was cause for marvel. In 1634, Father Paul Le Jeune wrote of the ruby-throated hummingbird, "God seems to me more wonderful in this little bird than in a large animal." As biological study progressed from description to analysis, body size proved to have a profound effect on an animal's requirements and habits. By knowing a bird's weight, we can now predict its metabolic and heart rates, insulation, flight speed; even its territory size and life-span.

The influence of body size can be appreciated by citing an analogous example: a spoonful of soup cools much faster than a kettleful. This is because smaller objects with their larger surface-to-volume ratios will cool more rapidly than bigger objects.

The temperature regulation of birds has been studied extensively in the laboratory, but the complexity of natural environments and of behavior in wild birds has caused ornithologists to largely ignore such regulation in nature. A nest is a good place to investigate this because a bird regularly returns to it and to temperature sensors and other measuring devices placed within it.

One of the functions of a bird's nest is to conserve heat, a form of energy. Yet keeping two eggs of the "Bigness of Pease" warm in a small nest must be a challenge for a hummingbird, considering the size of its body. Perhaps this is not a problem in the South American tropics, where hummingbirds probably evolved, but several species now breed and nest in the chilly climates of higher altitudes and latitudes. The combination of small extreme in body size and cold nights provides a dramatic opportunity for the study of thermoregulation.

A hummingbird that is not able to obtain sufficient food must conserve energy in order to maintain a balance. To do this, it can reduce its body temperature and enter a brief state of semihibernation, or hypothermia. However, development of the embryo is suspended while the egg is cool. By bugging the nests of Anna's hummingbirds (*Calypte anna*) in southern California, Thomas Howell and William Dawson found in 1954 that incubating females did not lower their body temperature. From that study ornithologists generalized that all incubating hummingbirds maintained normal body temperatures at all times.

The calliope hummingbird (*Stellula calliope*) is only three-fifths the size of Anna's hummingbird, yet it nests in the Rocky Mountains where temperatures are far cooler than in southern California. Because of its colder habitat and smaller size, I decided to use this species to test the generalization that incubating hummingbirds constantly maintain high body and nest temperatures.

In 1970, I recorded the temperature of a calliope hummingbird nest at the Jackson Hole Biological Research Station in Wyoming. The thin, dry atmosphere brings a chill to the valley each evening and temperatures often drop to freezing before sunrise. After placing a thermocouple—a device that continuously monitors temperature—in the nest (precariously situated eight feet out on a slender limb), I discovered that during the night, the female was able to maintain the temperature of the egg at from 95° to 97°F. A second nest along the Snake River showed similar temperatures. Despite my intrusions, both nests were successful; two chicks fledged from each.

The observations led to more questions. How does a female hummingbird pick a nest site? How important for her heat conservation are the insulation of the nest and the shelter from

the night sky that an overhead branch provides? Surrounding these questions is the more important one—how much energy is required to keep a nest warm?

Even cooler than Jackson Hole at night is the Rocky Mountain Biological Laboratory, situated at an elevation of 9,500 feet in Gothic, Colorado. A large population of broad-tailed hummingbirds (*Selasphorus platycercus*) breeds there. With the help of my family and assistants I have now studied more than 100 of their nests—some were in the low branches of Engelmann spruce and others were high in aspens.

Unlike small mammals that burrow underground, the hummingbird hen is directly exposed to a cold night and heat conservation is of utmost importance to her. A nesting bird must wait for enough light to begin feeding and can consume only so much before nightfall. With these limitations, the hummingbird hen cannot ignore conservation. Indeed, she is forced into economy by natural selection; spendthrifts do not leave offspring.

In order to measure nighttime heat losses from nests, elaborate and expensive equipment is necessary. Heat leaves the hummingbird and her nest by several routes. For example, the bird warms the surrounding air and when the air moves, the heat is lost by convection. Air and surface temperatures and wind velocity must thus be measured. Heat is also transferred through the nest by conduction, so nest interior and exterior temperatures are needed, as is a measurement of heat flow through the nest.

Any object warmer than the absolute zero of outer space radiates heat energy. The warmer the surface, the faster the heat radiates away. If the bird's back is warmer than either the overhead branches or the sky, her body will emit more heat than it receives and thus incur a net loss. At the coldest point in the daily cycle, just before daybreak, an incubating hummingbird loses heat by radiation, conduction, and convection at a rate of about one-quarter of a watt. This loss must be balanced by an equivalent heat production.

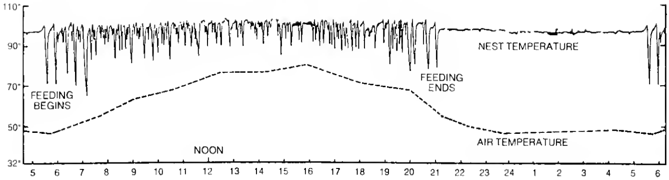
This rate of heat flow comes from a bird weighing only one-ninth of an ounce. The average person, when seated, burns energy at a rate of about 100 watts, which per hummingbird-sized morsel of flesh averages only 1/200 watt.

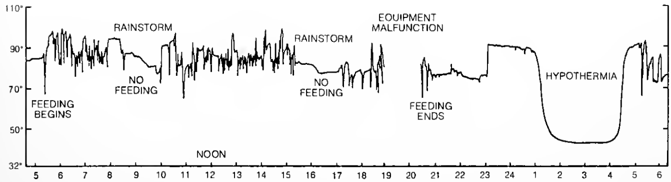
Energetically, a hummingbird's small body requires less food than a larger bird but more food in proportion to its size. It has the ability to feed on minute sources such as droplets of nectar and tiny insects that are generally unprofitable for larger birds to exploit. Finally, it has some time at its disposal. The game of life is one of converting that time into energy to maintain vital processes and to be able to leave offspring that can make the same conversion. Energy balance is mandatory. If the daily energy intake does not cover the daily requirements, the system starts disintegrating. If not reversed, death will follow.

The broad-tail is a mountain hummingbird breeding from Guatemala to northern Nevada, Utah, and Wyoming. The Rocky Mountain breeders probably winter in west-central Mexico and move north at the first sign of spring, arriving in the

During the latter part of the nesting season in Colorado, broad-tailed hummingbirds, such as this female, compete vigorously with rufous hummingbirds for nectar.

William A. Calder III





A sensor implanted in an artificial egg indicated that an incubating calliope hummingbird hen maintains an average nest temperature of 95° to 97°F despite a fluctuation of outside air temperature from 46° to 79°. The sudden cooling of the nest during feeding trips is represented by sharp drops in nest temperature. When severe thunderstorms (lower graph) kept a female broad-tailed hummingbird on her nest for prolonged periods, she missed several feeding trips. After midnight, the bird's body temperature dropped and she entered a state of hypothermia. Her temperature began rising, however, in time to enable her to begin feeding by daybreak.

Santa Catalina Mountains of southern Arizona in late February. The first reconnaissance flights to Gothic are in mid-May, and the birds usually arrive during mid-morning.

High in the Rockies, energy balance is precarious and strongly dominated by the weather. Late snowstorms or slow melting of a heavy winter snowfall will delay flowering of the Nelson's larkspur, which the hummingbirds seem to rely on for the onset of breeding. If the reconnoitering birds find the energy supply inadequate, they may feed a little from the pussywillows and then disappear by midafternoon, presumably retreating to an energy base at a lower elevation.

If the flowers are blooming, however, or if artificial feeders are up, the hummingbirds will remain—the males fighting over territories and the females examining potential nest sites. The uncertainties of late summer dictate that breeding must start as soon as possible. Either drought or early snowstorms may suddenly terminate the nectar supply.

After courtship, the male is not involved in the reproductive sequence. The female builds the nest with moss, lichens, and papery bark fragments, and lines it with cobwebbing and down from willows or aspens. She then produces two eggs, incubates them from 15 to 19 days, and broods and raises the chicks for 21 to 26 days. Throughout the incubation and brooding, she repairs and adds to the nest walls.

During this period, she must meet not only her own energy requirements but also those of her eggs or chicks, a responsibility threatened by the constant danger of a decline in food supply before the 36- to 45-day nesting period is completed. Matters may be further complicated by the arrival from late July to early August of aggressive rufous hummingbirds (*Selasphorus rufus*) migrating south. This species breeds earlier in the coastal forests from California to the northern coast of the Gulf of Alaska and inland from British Columbia and Alberta through Idaho and Montana. Although rufous hummingbirds inhabit low altitudes, during the peak of their migration they will normally feed in meadows that are higher than those in which the broad-tails nest. If the flowers are late blooming in the higher altitudes, however, or if artificial feeders hold rufous hummingbirds to the lower meadows, the two species will compete fiercely for the same food resources.

In this difficult period broad-tail nests with live chicks in them are sometimes abandoned. If the female cannot provide food for her young, she has no choice but to fend for herself and leave them to starve. Natural selection favors the opportunists that start nesting early enough in the season to precede the decline in resources but not so early that a late spring snowstorm would wipe out the effort.

Energy crises can occur on a daily scale as well as on a more prolonged one. The hen usually leaves the nest for her first feeding trip of the day approximately 11 to 18 minutes before sunrise and finishes the last at sunset. Nest-cooling records indicate that during the day the female leaves the nest to feed about sixty times. She also will make up to thirty shorter absences for preening, harassing potential predators, and catching nearby small insects.

Apparently, these feeding trips provide an energy balance with only

Hummingbirds aid in the cross-fertilization of tubular flowers like columbine. When this female rufous hummingbird probes for nectar, her head collects pollen, which she carries to other flowers.

William A. Calder

William A. Calder III

Bob and Clara Calhoun; Bruce Coleman, Inc.

While female broad-tails, above, incubate their eggs, males of the species, right, who rarely share in incubation or rearing, defend their territory from encroaching males.

a slight margin to spare. Summer rainstorms in the Rockies can be violent. During heavy downpours female hummingbirds must remain on their nests, thereby missing several feeding trips. On several of these occasions, the day's energy intake was significantly reduced because of lost feeding time.

This leads to an energy shortage as the hummingbird cannot obtain food before daylight. Since she must preserve enough energy to feed at that time, she reduces her energy consumption. In several nests we recorded temperature drops from 90° to 52° or lower between midnight and four o'clock when heavy rain had fallen the day before. The lowered temperatures lasted for several hours, but the bird's body began to warm far enough in advance of first light to enable it to resume feeding at that time.

Thus the hypothermia and resultant torpor, which I was seeking when I started studying hummingbirds, did actually occur. Because this was an infrequent occurrence, it did not indicate an inability to regulate temperatures. Cold night temperatures without previous rain did not necessarily produce lowered body temperatures. Hypothermia tended to occur during nights following a day of rain. Such nights generally were warmer than usual because the clouds reduced environmental cooling by radiation. Hypothermia was recorded twelve times in 1972 and 1973—during incubation, at hatching, and when chicks were six to thirteen days old. The rate of successful fledging in these nests was 63 percent, slightly higher than the success rate recorded for all nests studied, so the cooling does not seem to be detrimental, other than possibly slowing development for several hours. Through hypothermia, energy was saved and the crisis was met successfully.

A close relative of the broad-tail, the rufous is the smallest bird in Alaska. Breeding up to about 61 degrees north, the rufous holds the latitude record for hummingbirds. How do its energy problems compare with that of the broad-tail in Colorado? In 1974 and 1975 we sampled hummingbird life at Elfin Cove on Chichagof Island and around Cordova and Juneau. Possible challenges to the energy balance of these high-latitude birds include the climate, the food supply, and the demands of migration.

Hummingbirds in Alaska have long days for feeding during the summer. Consequently, their overnight fast is relatively brief, averaging about four and one-half hours. The ratio of feeding time to fasting time probably makes it easier to attain an energy balance. The gentle, diffuse

rainfall is another factor that encourages stability because it permits hummingbirds to feed while it rains. The daytime air temperature is not as high as in Colorado, but the clouds and moist air reduce nighttime cooling. The net result is that the potential for heat drain from hummingbirds is similar in Alaska and Colorado.

In Alaska, rufous nests were embarrassingly difficult to find, but the interior temperatures of those that we did locate were similar to those of broad-tails in the Rocky Mountains. Unfortunately, one nest was destroyed by a red squirrel ten days after we began recording temperatures. Other measurements were taken from a nest on the Argetsinger Environmental Campus of the Juneau-Douglas Schools. We had to disregard these data, however, when we found that the nest's interior was lined with fiber glass insulation from a nearby cabin.

The food supply in Alaska remains to be studied quantitatively. The hummingbirds appear to feed from flowers that probably evolved for pollination by bees. Such flowers are blueberry, salmonberry, and *Menziesia*. These grow in greatest profusion where man has altered the vegetation—along road cuts and on logged-over areas. Only at the end of the nesting season do flowers bloom that are specialized for hummingbird pollination. Red columbine and Indian paintbrush—which have tubular-shaped flowers—are among them. Hummingbirds probably inhabited Alaska only recently, perhaps only since the Pleistocene. The spread to this region of flowers specialized for hummingbirds has lagged behind that of their pollinators. Most hummingbirds in Alaska must therefore get their food from flowers usually pollinated by bees.

Advancing from a tropical heritage, the world's smallest birds have successfully exploited the nocturnally chilling climates of the Rocky Mountains and the Alaskan coast. Their success appears to be based on conservation of energy attained by careful insulation of the nest, by choosing a strategically located nest site, and by conserving heat when an energy shortage occurs. Perhaps we need a second national bird, one that attains energy balance through conservation. □

Earthquake Hazards in the Mountains

by Kenneth Hewitt

Why did a moderate quake in Pakistan cause severe damage and loss of life?

At 5:11 P.M. on December 28, 1974, an earthquake of magnitude 5.5 on the Richter scale shook the mountains of Indus Kohistan, in the north of Pakistan. Great devastation occurred over an area of some 300 square miles. Thousands of people were killed and several times as many injured. Whole villages were razed and the economic base of the region badly dislocated. Homes, bazaars, and recently built schools, uncounted tiers of terraced fields and irrigation systems were shaken apart by the tremors or crushed by the rockfalls and landslides that followed. Large numbers of cattle, buffalo, and goats died, often buried, as were so many of the human casualties, in buildings that had been their shelter against the hazards of winter. The Karakoram Highway, Pakistan's costly and prestigious new trade route to China, was blocked or swept away by hundreds of landslides for a distance of some forty miles.

Indus Kohistan is a land of deep gorges and high mountain ridges at the western end of the Great Himalayas. The lowest parts, where the Indus cuts a narrow slot from the trans-Himalaya to the plains of the Punjab, are barely 2,000 feet above sea level. The adjacent mountains rise to between 10,000 and 15,000 feet. Steep slopes, thousands of feet from top to bottom, dominate the landscape and offer a huge store of potential energy when earth or boulders start to move over them.

The many tributary streams hurry to join the Indus through steep, narrow gorges flanked by precipitous slopes. Bare rock walls are undercut by the rivers at many points. The region is one of active, vigorous folding and faulting, where the Himalayas are crushed into the tight pleat between the Hindu Kush and the Karakoram Himalayas.

Strong upslope variations in climate are common in such terrain, and played a key role in the impact of the earthquake. Perhaps a quarter of the affected population lived in the higher, snowbound areas. The survivors up here fared much worse than those at lower elevations where, if one found shelter from the cool valley winds, it was comparatively mild. At higher, more exposed elevations, people had great difficulty constructing shelters and finding warmth. They faced enormous problems carrying the injured downslope, and relief supplies upslope, over steep, snow-covered paths that were blocked or borne away by landslides at many points. In such terrain it is never good to be sick in winter.

When undisturbed, all but the steepest valley sides support a fairly dense forest cover up to 13,000 feet. It is dominated mostly by the deodar, the Himalayan cedar. Where the forest remains, there was far less damage than elsewhere; in particular, there were few rockfalls. But much of the forest has been cleared and most of what remains is overused. The incessant search for firewood, *the* energy source for cooking and keeping warm, has overreached the supply even here, although not to as extreme a degree as farther out in the foothills. The ever present herds of goats have also taken their toll through overgrazing and destruction of young trees.

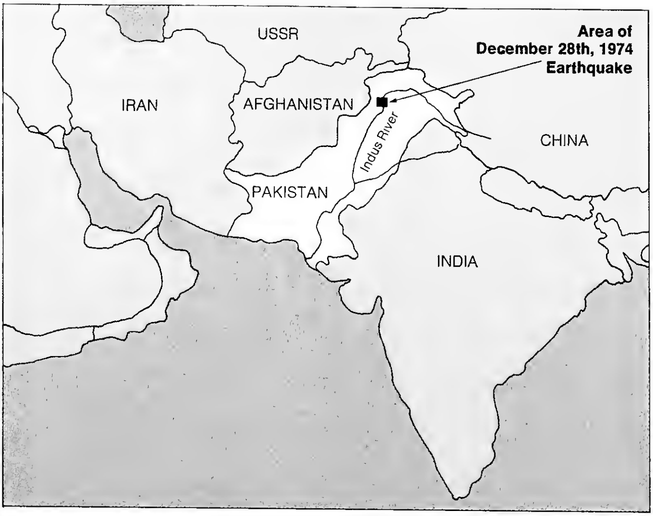
So most farms and villages are surrounded by deforested slopes. Many are terraced, of course, and may rise more than 2,000 feet without a break. In the winter, bare soil and loose rock—unstable debris easily set in downslope motion by the earthquake—are conspicuous around and above settlements.

The immediate causes of damage during the earthquake were about equally divided between the effects of the ground motion itself and the impact of rockfalls and landslides set off by the earth tremors. Ground motion caused the shaking apart of structures and, especially on steeper slopes, the breakup and slumping of the ground itself. Disintegrating retaining walls or downslope slumping of the soil body damaged many terrace walls; the collapse of buildings was also due, in perhaps half the cases, to ground motion or failure.

But everything depended upon location and local terrain. Larger settlements, such as Pattan, are on broad river terraces or alluvial fans where the valleys widen. Here ground motion was decisive in the amount of damage. Apart from being less exposed to landslides from steep slopes, these areas have deeper alluvial sub-

The steep, deforested slopes of northern Pakistan make the area more vulnerable to damage when an earthquake occurs. These houses of mud and wattle with strong timber supports withstood tremors well.

Kenneth Hewitt



soils where ground movement is generally more severe in earthquakes.

Conversely, farms and villages in the steep-walled tributary valleys and narrows of the Indus suffered mainly from the terrible rain of boulders following the tremors. The results were more like bomb damage. Landslides were also a large factor in the destruction of irrigation channels and terraces here. Moreover, landslides are a particularly bad way for terracing to go. The entire soil element is swept away, sometimes directly into a stream bed and downstream before it can be recovered. Here, it probably ended up in Tarbela Dam, a huge irrigation and power project some 75 miles down the Indus. Since sedimentation is a major problem in the economic lifetime of the reservoir, agricultural productivity was thus diminished at both ends.

The special and most terrifying feature of an earthquake is that, more than any other natural hazard, it attacks our shelters and man-made structures. Nearly all types of buildings in Indus Kohistan fared badly in the disaster—modern *pukka* buildings of dressed stone and mortar or concrete, as well as traditional *kutcha* work in mixtures of mud, wattle, timber, and boulders.

A few old and traditional buildings did as well as any modern structures. If their walls and roofs were made of sound timber, wood-frame houses of traditional design fared best of all. Studies elsewhere have shown that small timber-frame buildings do well in earthquakes. But when individual walls and building blocks can move independently or when the material is rigid and brittle, buildings readily shake apart.

Wood supplies, however, are diminishing or becoming more costly, the result of destruction of forest cover, expanding populations, and the heavy demand from urban centers better able to pay the price for wood. This means that less and poorer timber is used and that existing timber structures are renovated less often.

In Indus Kohistan, one practice that seems a response to timber shortages proved fatal during the earthquake. That is the decision to put all or the best timber into the roof, which is supported by walls of mud and stones or even dry-stone work. In this area, roofs are important social and economic spaces, used for gatherings, for women to work outdoors in warm weather, and for drying produce in the sun. Roofs are, therefore, solid structures of timber, wattle, and hard-packed mud. And they are very heavy. Again and again during the earthquake, the roofs fell in single, crushing masses, while walls merely crumbled away in the tremors.

At Palas, a tragedy within the tragedy when the massive roof of an old mosque collapsed while the entire adult male population was at prayer. Only one survived, and he sustained serious head injuries. The collapse of this otherwise solidly built structure was due to the old, rotten timber in the walls. The sad fate of all buildings at Palas seemed to reflect the wide treeless slopes or poor scrub in that area, forcing builders to make do with inferior or old timber.

In terms of social and economic disruption, however, damage to terraces and irrigation systems may be more critical than that to buildings and second only to human casualties in its significance. The terraces are the main economic base for the majority of the population. A few groups specializing in herding own most of the livestock, a useful source of income, clothing, and to some extent, food; but irrigation agriculture, with maize the main crop, is much more critical.

With annual precipitation at only 28 to 40 inches, drying valley winds, and seasonal drought, irrigation is essential. It involves elaborate systems of ditches. Pipes and troughs hewn by hand from whole logs lead the water across the valleys and around cliffs to areas of terracing. Water also powers the hundreds of small mills that grind the grain into flour. Meanwhile, not only the retaining walls and water channels but also the soil itself is a human artifact. Fertile terrace surfaces are built up over decades, even centuries, with baskets of alluvium, manure, and night soil; the fine sediment in irrigation waters; and carefully planned cropping patterns. Loss of such soil is only reversible over similar periods, and then only with a substantial input of labor. For the moment, therefore, soil loss constitutes a large reduction in the productive land surface and/or depth of fertile soil. In turn, this reduces the number of mouths that can be fed. Since earthquake damage was most severe in the poorer and more marginal areas—recently colonized in response to increased population—the soil loss is likely to put greatest pressure on those people least able to offset it.

Elsewhere, the secondary effects of earthquakes, such as fire and disease, have produced more damage than the initial impact. Surprisingly, given the amount of wood and wattle

in many buildings in the region and the close-packed nature of the villages, fire was a minor agent in the catastrophe. Of course, there are only a handful of gas or oil stoves in the region and no pipelines—the most likely sources of conflagration.

Although no outbreaks of disease were reported, they probably did occur. For two or three weeks following the earthquake, many farms and villages were bathed in the stench of dead cattle and goats, the bloated bodies being fed upon by domestic fowl and dogs, as well as wild scavengers. Often, groups of children played numbly around them. Here was one of the ironies of relief operations: some villagers were reluctant to remove the carcasses before an official count, for fear they would lose compensation!

Every disaster has its special features, its unique combination of circumstances, warranting detailed appraisal. Here we can but sketch the conditions in Indus Kohistan. At the same time, it was only one of more than thirty earthquake disasters of comparable or larger magnitude that have occurred in mountainous regions over the past quarter of a century. Most of these have been in Third World countries.

For the world as a whole, an average year in the mid-twentieth century brings some thirty-two major natural disasters. Of these, four are earthquake triggered, accounting for some 14,000 fatalities. High mountain regions are areas of concentrated seismic risk, notably in the western cordilleras of the Americas, the Eurasian and African mountain chains from Morocco to western China, and the mountainous islands of Southeast Asia. While nearly 70 percent of potentially damaging earthquakes take place in the circum-Pacific belt, only 20 percent of the mid-century (1949–69) casualties were reported here. But the Himalayan-Mediterranean zone, from Burma to Morocco, with only 14 percent of dangerous earthquakes, accounted for nearly 75 percent of the casualties. Clearly, there is a relation between the relative density of human occupancy and earthquake risk.

There are strong indications that the number of natural disasters and the degree of damage in general have increased in this century. Since there is no reason to suppose that nature is becoming more severe, the origin must be sought in changing human activities. In wealthy nations, the level of economic losses is increasing; in poorer countries, both mortality and economic loss are expanding. The disaster in Pakistan serves as an example of the extent of the problem, while at the same time offering a case study in possible strategies for rehabilitation.

First, the scale and frequency of such disasters in high mountains is not merely a result of seismic conditions but rather the worst expression of recent socioeconomic pressures and environmental deterioration. Rapid deforestation, overgrazing, and the extension of cropping to ever more marginal areas, all of which accelerate erosion, flooding, and silting of bottomlands, are spreading rapidly throughout the world's tropical and subtropical high mountains. One of the effects of this convergence of environmental damage and socioeconomic stresses is to greatly enhance the risk from pests, disease, landslides, floods, and earthquakes.

In many regions, the processes of environmental damage are far more advanced than in Indus Kohistan, but it would be erroneous to imagine that this is anything but a matter of time. Between visits in 1962 and 1975 to the Himalayan tracts of Pakistan closer to the plains, I found a staggering increase in forest damage, bare slopes, gullying, and landslides. The potential damage from an earthquake there is very great indeed, not least in the enormous pulse of sediment it would hurry into the rivers, dams, and irrigation works so vital to Pakistan's survival.

The situation is aggravated by the loosening of ties between people and their land. As more and more men work in the cities as factory hands,

Solid, heavy roofs often fell in single masses during the earthquake, the result of putting all or the best timber into the inadequately supported roof.

Kenneth Hewitt

servants, drivers, and so on, farm plots are often just supplements to other income, or convenient homes for women and children who return in summer to work them. Similar loosening of ties, including the erosion of concern for the local environment in favor of hoped-for financial returns, is seen throughout high mountain areas.

As in western Europe more than two centuries ago, rural landowners and peasants moving into the urban labor force yield the land up to whoever is best able to profit by it in the marketplace or, if it is "uneconomic," to abandonment. The extent of such transformation has accelerated markedly in recent years. It seems that all the other political, economic, and technological forces that have followed the various revolutions in land tenure, work, resource use, and government elsewhere have suddenly burst full tilt into these lands.

More often than not, environmental damage and natural hazards merely aid the chaotic dismantling of indigenous cultures. I am not implying that the over-all trends can or should be halted, least of all that the indigenous cultures should be "preserved." But when later phases of this development in marginal lands bring great ecosystem damage and high risk from natural extremes, it is hard to condone a laissez faire attitude. In many respects those best able to avert the worst effects—scientists, international agencies, and planners—seem least equipped with the concern, if not the tools, to do so. This comes out clearly even in the emotionally charged area of a disaster.

Let us examine, for example, a strategy for rehabilitating the Indus Kohistan area that would take full account of the local habitat and economy. Remember, damage to the habitat has not yet gone so far that it could not be restored in a small number of years. The people are sturdily independent, hardworking, and not yet ready for the climactic abandonment of old ways and land that is happening elsewhere. And unless one compares it with the rich agriculture of the Punjab plains the area appears productive and could be more so with improved labor-intensive cultivation.

In such terms, rehabilitation programs should include direct support for restoring and improving the quality of existing agriculture, including assistance in better terrace construction, crop varieties, animal health, and incentives to pull back from precarious slopes. Programs are also needed to improve health care and provide education and advisory services, using modest means, which can be easily modified if unsuccessful, and technology that can be maintained under the local conditions. Earthquake proofing, for example, should start with existing building practices, rather than exotic engineering notions.

Afforestation, since it offers benefits in all areas, from environmental protection to resources for improving building quality, should be at the core of any rehabilitation program. But it must be a mixed strategy, not lines of trees marching up and down every mountain. Afforestation must include pure stands of timber on vulnerable watersheds, with shelter belts and avenues along roads and paths. There must be farm forestry with, say, fruit and nut trees carefully selected and planted to improve terrace stability and provide additional income without interfering with grain cultivation; trees whose leaves will provide fodder, but also areas from which grazing must be excluded; commercial lumber stands for eventual export and avenues of quick-growing trees in villages and on farms to provide for local constructional timber.

The Pakistan Forestry Service has, in fact, conducted some fine experiments of this kind. The main problem is always a mandate and funding, especially money to subsidize replacements such as oil stoves and kerosine for overtaxed firewood resources and to compensate shepherds for obeying stricter grazing laws. Tree planting is the least of worries!

In the case of the earthquake, however, funds are available. The aftermath of an earthquake provides a unique psychological opportunity for government to enter into ventures that will uplift marginal areas and draw them into fruitful relations with the larger political community.

Actually, Pakistan's prime minister has long argued for major afforestation and uplift of marginal regions. Unhappily, these hopes get lost somewhere in the system, and so far

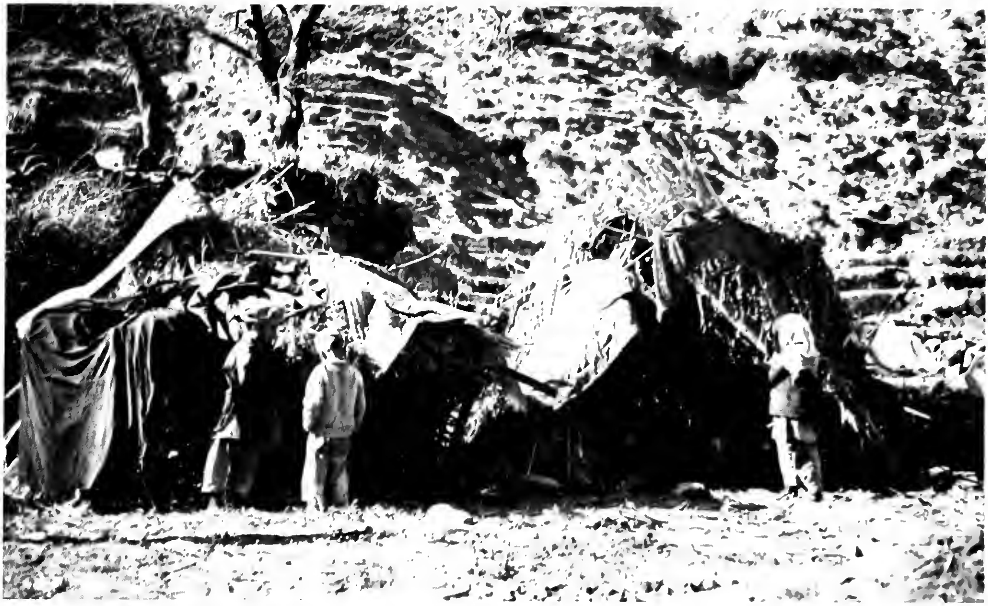
Following the 1974 earthquake, Pakistani villagers put up shelters made of maize stalks and the wreckage of homes.

forestry has taken second place every time. The cities and industries grow apace, but forests disappear, soil erosion worsens, and so does the plight of rural peoples.

In terms of combating earthquakes, the overwhelming issue for scientists has been that of prediction. It now seems likely we will indeed have some working systems for earthquake forecasting in a few areas in the present decade. But the techniques require either extensive seismological instrumentation or a high degree of organized observing and understanding on the part of people living in earthquake zones. To be effective, the observations must embrace a large area. Forecasts must be rapidly disseminated and followed up by evacuation and other safety measures. Outside of a few major centers, such a program has little prospect of implementation throughout the vast, high-risk regions in mountains from Burma to Morocco, in East Africa or Andean South America.

Similar problems arise with the engineering principles and building-code requirements developed in affluent nations. Where implemented, they can indeed be highly successful, as they have been in Quetta, Pakistan, reconstructed after the 1935 earthquake that killed more than 50,000 persons. Unfortunately, in mountain regions few buildings, even the most modern, meet minimal standards. More importantly, the temptation everywhere is to build cheaply and quickly. Recent earthquakes in rural

Where the terrain is fairly flat, as in this recently struck area of Guatemala, the soil tends to break apart, rather than collapse. Here, too, poor building materials contributed to the extensive damage.



Kenneth Hewitt

Roger Sherman

In Pakistan, landslides and rockfalls caused as much damage as ground motion and figured heavily in the destruction of terraces. When terracing collapses, the soil is swept away; in this case it ended in a dam 75 miles down the Indus River. Rockfalls also crushed buildings, including a bazaar, far right, along the Karakoram Highway.

Iran, Turkey, Venezuela, Peru, and Guatemala, as well as Indus Kohistan, show the vulnerability of peasant construction when poor materials and sites are used. But what government can enforce building codes throughout these high-risk areas, let alone commence the rebuilding of millions of structures?

I do not wish to demean the important work being done in seismology and earthquake engineering. Our world has become too urban and industrial not to need it. But in marginal habitats it smacks of those unconscious assumptions that we also take for granted when imposing Western technology on exotic cultures. In the deserts, tundra, and high mountains, one sees how much we apply our flatland, temperate technology and economic standards.

About 25 percent of the world's land area lies above 3,000 feet and some 10 percent has that combination of altitudinal range, topography, and climate one associates with alpine conditions. Perhaps 5 percent of the world's population lives in high mountains, notably in the tropical and subtropical regions. In other words, these regions have roughly the same

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weight in area and population as the United States.

For some nations, such as Peru, Ethiopia, and Nepal, mountains form the dominant habitat. In others, they provide essential resources such as minerals and timber or, as in Egypt, Pakistan, and Soviet Turkestan, the water supply for dry plains. Elsewhere, they have vital strategic importance, while affluent nations emphasize their value for recreation and as wildlife refuges.

Yet, environmentally, their greatest importance is as watersheds regulating the flow and quality of surface waters in many of the most populous lands. Conditions in the mountainous headwaters determine the incidence of floods in, and the amount of sediment carried by, such rivers as the Amazon, Indus, Ganges, and Mekong all the way to the oceans. Ecosystem damage in those headwaters affects human and other populations far beyond the mountains.

Looking at mountains with a "flatland" perspective, we treat them as obstacles because we have not devised technologies with them in mind. Economically, they are assumed to be marginal for all but a few special activities—as scenic resorts perhaps or mineral emplacements. Surely these views, however unconsciously applied, are environmentally disastrous. Moreover, they are economically fatal for Third World countries with large populations dependent on mountains, whether for living or for their water. If scientists, planners, and international agencies do not recognize these issues, neither will governments. The results of such myopia will be ever greater deterioration of marginal ecosystems and more devastating losses from natural disasters. □

A Pocketful of Crystals

by Vincent D. Manson
photographs by Henry Janson

In the Museum's new Hall of Minerals and Gems, beautiful objects record the geologic history of the earth

Along with animals and plants, minerals make up one of the earth's three great natural "kingdoms." Unlike the other two, however, minerals are inorganic and solid materials. About 2,500 different mineral species are known, ranging from common rock salt and pencil "lead" (actually graphite) to rare gemstones, such as sapphires, rubies, and emeralds. Some minerals, for example, copper, gold, and silver, are elements, but most are chemical compounds. Although they vary greatly in appearance, the crystal structure of minerals gives them a characteristic form, luster, and hardness. In addition, each mineral species also has a characteristic range of color.

Minerals result from the interaction of specific geologic processes, and being crystalline solids, they preserve the story of their past history. They thus enable us to learn about events that took place both at and beneath the earth's surface long before man existed to record them. By examining the formation of one particular mineral, in this case, tourmaline, we can learn something of the geologic history of the earth and glimpse the intricate interplay of forces involved in all mineral creation.

Tourmaline is the most abundant gemstone found in the United States. An important source is the granitic pegmatite of southern California. In this locale, its history goes back about 50 million years to the time when the earth's crustal plate carrying the North American continent collided with the Pacific plate, which bore the vast ocean. We do not know in detail why such plates suddenly shift and move in opposition. But that this happened is clearly shown by the record it has left. When the plates collided, what is known today as California felt its first earthquake. The more buoyant continental plate overrode the Pacific plate. The ocean floor, rich with mineral sediments built up by centuries of erosion on the North American continent, was forced below. It slid under slowly, moving only three or four centimeters a year, but miles and miles of rock and crust were pressed against each other in the process. The forces involved created an intensity of heat that had far-reaching consequences.

As the Pacific plate was swallowed underneath the American plate, some of the rich mineral deposit on the Pacific Ocean floor was recrystallized into new forms. Much of it, however, did not recrystallize, but was sweated out of the transformed sediment. A paste composed of chemical elements was formed. This paste of rich, mineral-bearing, molten material, known as magma, moved into the rock above and forced its way up into the earth's crust, filling whatever cracks and crevices were present. Enormous magmatic bodies were formed within the crust. The largest, which survives today, reached 1,000 miles in length, 50 miles in width, and a depth of 15 or 16 miles.

As the magma rose from the interior toward higher levels within the earth's crust, it began to cool. The cooling may have taken as long as

(*Continued on page 45*)

***Native Copper** (7" x 12" x 5")*
Copper uncombined with other elements has been extensively mined on Michigan's Keweenaw Peninsula, the area from which this specimen comes. Single masses of the mineral weighing up to several tons have been found in the same locale.

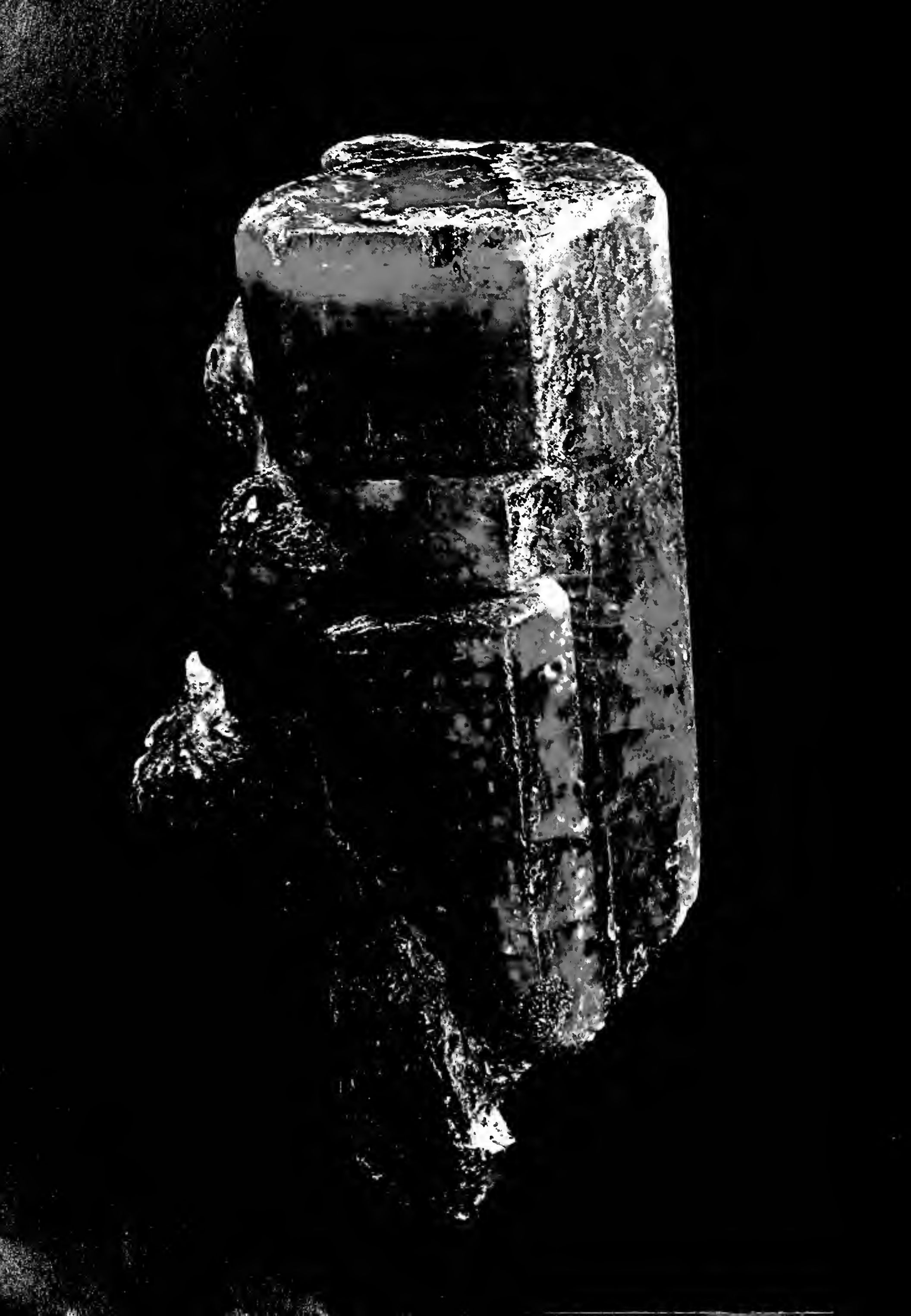
The minerals and gems shown here are from the collection of The American Museum of Natural History.

Elbaite Tourmalines

Tourmaline has an immense color range. It can be found in pink, green, blue, orange, brown, yellow, black, or colorless varieties. The crystals on the facing page (8" x 10" x 8") were unearthed 100 years ago in the Pala Chief mine in San Diego County, California. They show clearly how tourmaline is associated with other minerals. The pink crystals are tourmaline. The colorless ones are quartz. The dark crystals on the left of the base are columbite. The rest of the base is an intergrowth of lepidolite and cleavelandite. The specimen shown above (5" x 12" x 5") comes from Virgin des Lappes, in Gerais, Brazil—a large producer of gem tourmalines.

***Proustite** (1½" × 3½" × 1")*
Commonly called ruby-silver ore, the specimen above comes from Chanarcillo, Chile. Proustite is sensitive to some wavelengths of radiant energy. After long exposure to daylight, it turns black.

***Stibnite** (3" × 8" × 3")*
The crystals on the right come from Ichinokawa on the Japanese island of Shikoku, the most famous locality in the world for unusually large and well-developed stibnite. The mineral is soft and fragile. It will fuse in the heat of a lighted match.



100,000 years, and while it was going on, part of the magma crystallized, forming igneous rock. Constricted on all sides and subjected to continuous pressure from the plates, the rock could only move upward. Subjected to weathering and erosion, the rock was shaped into great granitic mountain ranges—the Sierras and the Rockies of today.

However, not all of the magma crystallized as granite at first. Some magmatic liquid remained; its water content increased, making it more fluid than the crystalline mush surrounding it. This residual magma then flowed through cracks and crevices in the granite toward the uppermost regions of the earth's crust. As the residual magma neared the earth's surface, it was subjected to cooler temperatures—500 or 600 degrees Celsius instead of 1,000 degrees or more. When this enriched magmatic material began to crystallize, it formed great white masses of pegmatite, composed principally of crystalline quartz and feldspar. These bodies of rock, perhaps 100 yards long and 20 feet wide, were embedded in the crust adjacent to the already crystallized granite. Within the pegmatite, as crystallization proceeded, pockets of enriched liquid remained.

These various-sized pockets were the birthplaces of tourmaline. Some of the entrapped liquid in them evolved into typical pegmatite. But once again, not all of the liquid crystallized. The remaining liquid was continuously enriched in some chemical elements, and finally crystallized into tourmaline and other rare minerals.

If this process could be observed, the pegmatite with its liquid-filled pockets would be seen as incandescent. The tourmaline crystals that form would have a more intense color than the common crystals of the pegmatite. As the tourmaline crystals form, removing chemicals from the liquid, the water content of the liquid increases and some of it turns into steam.

The pocket eventually becomes filled with steam, which increases the internal pressure. If the steam remains, the newly formed tourmaline crystals will become unstable and will dissolve. Sometimes the pegmatite surrounding the pocket is not strong enough to withstand the pressure, and the steam then bursts forth in an explosive rush. As the steam escapes, it shatters some of the confining rock and some of the tourmaline crystals. In the explosion other crystals are severed from the pocket walls, their tips falling to the floor. Cracks appear in many crystals, long milky-white lines that may either enhance or mar the tourmaline's beauty. But some of the crystals remain untouched and survive for eventual exposure as they were created.

In this final stage, the pocket is left to cool. The tourmaline's creation is complete. For the next thirty or forty million years, the Pacific plate continues to move under the American plate. Magma and granite continue to form. The mountains are pushed upward, carrying with them the pegmatite pockets and the tourmalines within them. Finally, with weathering and erosion at the surface, the tourmalines may be exposed to human discovery.

The story of the evolution of these tourmalines is comparable to the development of all other minerals. Each mineral is witness to a part of the history of the earth and the creation of the physical landscape that surrounds us.

Vincent D. Manson is a consultant to the Department of Mineral Sciences at The American Museum of Natural History. He was the scientist in charge of the concept and planning of the Museum's new Hall of Minerals and Gems, which will open on May 21.

***Beryl Variety Emerald** (1½" x 3½" x 1½")*
Found in the Ural Mountains of Siberia, this emerald has exceptionally vibrant color. Resting on a matrix of biotite schist, the crystals are joined in a parallel growth typical for emeralds.

City Snakes, Suburban Salamanders

by Frederick C. Schlauch

Urbanization often results in the drastic decline of reptiles and amphibians. But some species in the northeast megalopolis have not been crowded out by man

Long Island. For sociologists and demographers, it has been the classic northeast representation of the post-World War II suburban boom and sprawl that enlarged the concept of metropolis to megalopolis. To real estate speculators and developers, it was a bonanza, bringing profit by the lot, as was one of its western analogues, Los Angeles.

Long Island stretches about 120 miles from the tip of its western end, facing Manhattan, to the tip of its eastern end at Montauk Point. Bounded on the north by Long Island Sound and on the south by the Atlantic Ocean, scalloped by great bays and fringed by barrier beaches, the 12- to 20-mile-wide island was formed and shaped by glacial action and post-glacial forces. At the western end of the island, the city of Brooklyn flourished during the nineteenth century, and by 1898 it was the third most populous city in the United States. In that year, Brooklyn and the adjacent county of Queens were annexed by New York City and the two came to account, in recent decades, for a majority of the population of the biggest city in the country. Agriculture had destroyed segments of the formerly continuous wildernesses of Nassau and Suffolk counties, but much land still remained untouched by the plow.

Then came automobiles and the early paved roadways. Starting in 1945, World War II veterans, stimulated by G.I. benefits, flocked from the central city to the mythical land of the suburban dream. Tract development spread across the landscape, engulfing nearly all of the great Long Island prairie known as the Hempstead Plains and spreading to the deciduous forest of the North Shore. It is now eating away the wilderness of the Long Island Pine Barrens.

In 1900, the combined human population of the island's four counties—Kings (Brooklyn), Queens, Nassau, and Suffolk—stood at less than 1,500,000. By 1970, the figure had exploded to more than 7,000,000. Today the population is still climbing and cramping into the available space—less than 2,000 square miles.

Increasing population and the asso-

E. R. Degginger

As a network of tract housing spread across the landscape of Long Island after World War II, suitable habitats for many reptiles and amphibians were reduced to discrete pockets. Most salamanders require ponds or streams in which to lay their eggs. The red-backed salamander, right, uses moist ground litter for this purpose, and its young are capable of a terrestrial existence upon hatching. These traits make it more tolerant of urbanization.

George Rockwin

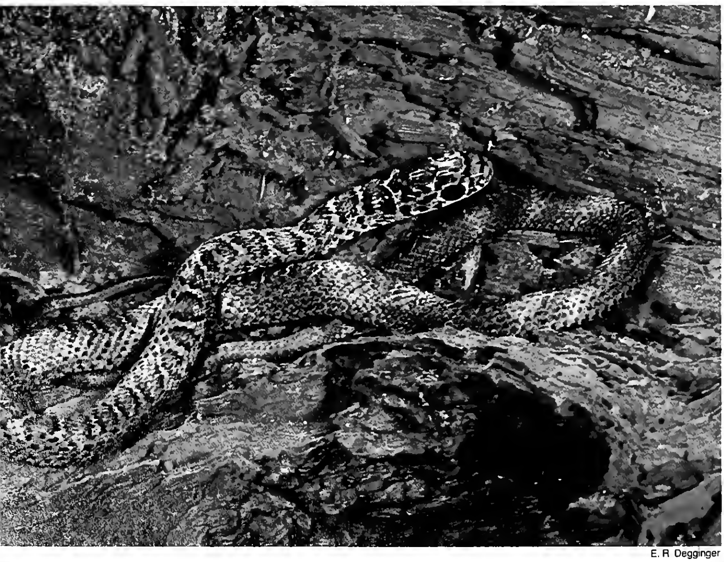
ciated urbanization have had a documented effect on the human character of the island. Historical and regional planning reports are packed with sociological and demographic information. However, data about the impact on the animal life of the island are scarce, and where information does exist in such reports, it usually proves superficial and often erroneous. But there can be no doubt that the impact of urbanization on the island's fauna has been enormous.

Many people, believing that human population growth is always antithetical to the survival of wildlife, make the assumption that Long Island—now a region characterized by one of the densest human populations in the United States—must be devoid of most of its original wildlife. Most field zoologists do not care to investigate regions such as Long Island, and most of the animal ecologists in the universities and museums on or near the island do their field research elsewhere, in relatively undisturbed wildernesses hundreds or thousands of miles away. Thus, the actions of professional biologists have reinforced the popular notion that Long Island is virtually lacking in wildlife. The current status of the amphibians and reptiles on this island reveals the fallacy of this preconception.

For more than a decade, I have intensively studied the salamanders, snakes, turtles, and frogs and toads of Long Island. The island functions as an excellent field gradient for urban zooecological research. The general trend is toward decreased urbanization as the island's eastern end is approached. The west end, comprised of two New York City boroughs (Brooklyn and Queens) and Nassau County, is the most heavily developed section of the island. Yet, at least 28 of the 37 species of amphibians and reptiles definitely regarded as native to Long Island have been found at one or more localities on the west end during the past fifteen years, while to the east, in the less developed area of Suffolk County, at least 35 of the 37 species have been recorded.

While comparatively few species have been exterminated, it cannot be said that urbanization has adversely affected only those that have disappeared. The majority of the remaining species have declined in numbers as a consequence of urbanization, and some formerly widespread species are now restricted to disjunct tracts of suitable habitat. For some species, however, urbanization may actually

A semiaquatic species, the ribbon snake, right, has been adversely affected in urbanized areas throughout its range in the eastern United States because of the alteration of its swampland habitat. The northern black racer (immature specimen, below) attains a length of up to six feet. This snake probably has a large home range, which could account for its disappearance from most of Long Island's urbanized west end.



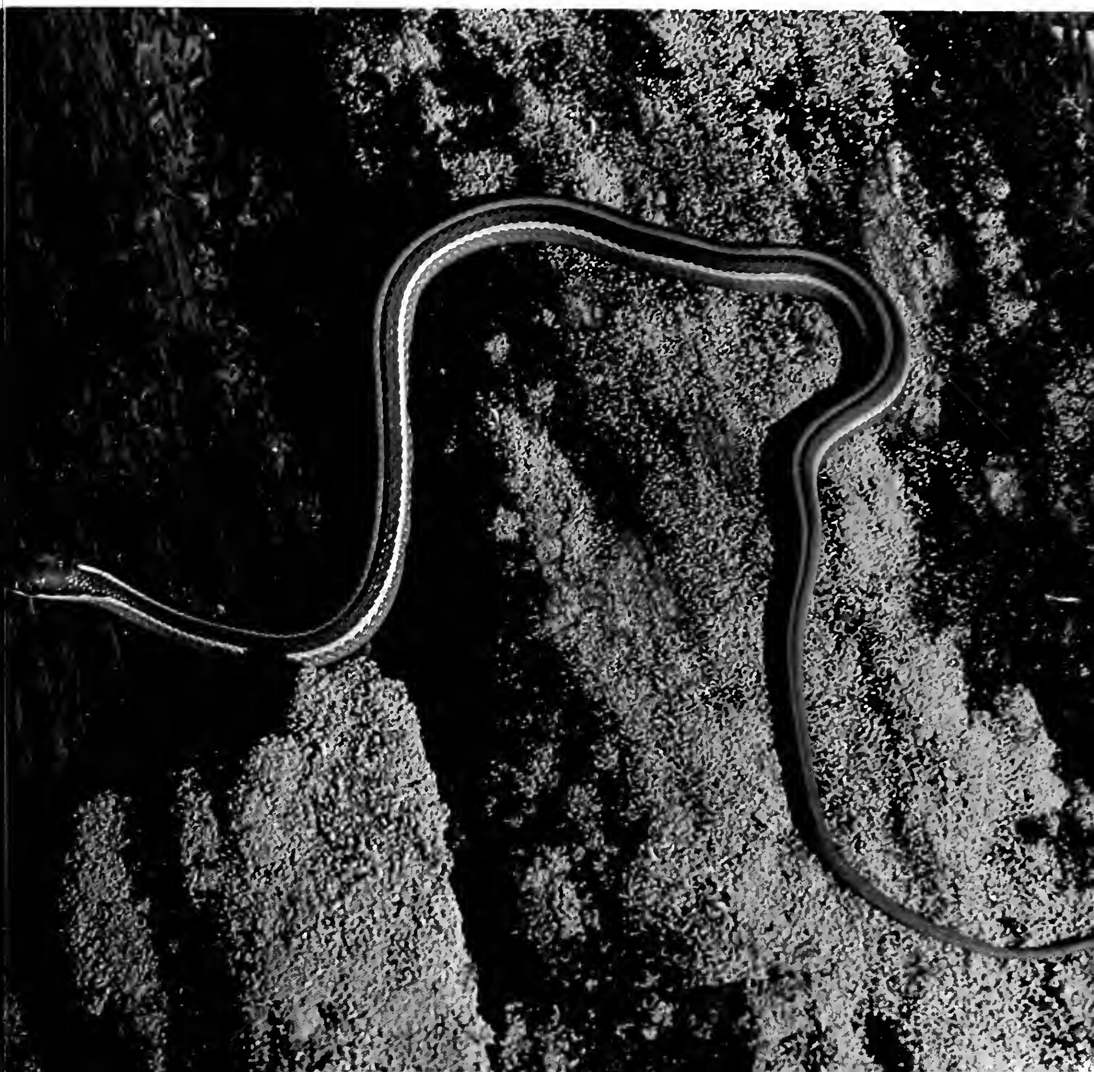
E. R Degginger

have brought increases in population, at least on a local basis.

Generally, it would appear that those species of herpetozoans with the more specialized and complex environmental requirements are the most sensitive to urbanization. Consider the four salamanders of the genus *Ambystoma* indigenous to Long Island: the blue-spotted (*A. laterale*), spotted (*A. maculatum*), marbled (*A. opacum*), and eastern tiger (*A. tigrinum tigrinum*). All four spend most of their adult lives in woodlands, but, during their breeding seasons, they migrate to local ponds. Each species migrates once per year: the blue-spotted, spotted, and tiger in late winter or early spring; the marbled in autumn. The aquatic larvae of the spring-breeding species take a few months to attain a capability for terrestrial locomotion; the autumn-breeding marbled salamander takes eight or nine months.

With the exception of the blue-spotted, all the species originally were fairly widespread and continuously distributed on Long Island. Now the ranges of these salamanders are much smaller and more disjunct. We can theorize on the events that caused this decline [illegible]. Knowledge of the life [illegible] of salamanders, together with [illegible] vations on how urbanization [illegible] the physical and biological [illegible] the environment [illegible] elsewhere where the [illegible] still be found.

Urbanization may have interfered with the life histories of the salamanders by eliminating or disrupting breeding ponds. Such ponds may have been filled or drained to create dry land for construction projects. Long Island households secure their drinking water through an under-



E. R. Degginger

ground pumping system that lowers the water table, and this may have caused some seasonal ponds to dry out too early in the year for salamander young to become terrestrially competent. Industrial pollutants added to the air cause rainwater to become more acidic; without any other alteration of the habitat, urbanization may have changed the pH of pond water so drastically as to prevent salamander eggs from hatching or the larvae from developing properly. Even in areas where ponds remain undisturbed, the salamanders may have disappeared because urban development has reduced the surrounding woodlands.

The *Ambystoma* are relatively large salamanders, and species of this genus are sold by the pet trade. The eastern tiger, for example, is a robust species known to attain a length of 13 inches. Virtually an entire population of such salamanders at a breeding pond may be wiped out by greedy pet dealers or pet-seeking children.

Only a few highly localized populations of *Ambystoma* remain on the west end. Fortunately, a number of populations still thrive farther eastward, but even these may soon decline beyond possible recovery, and any endemic genetic characteristics of west end *Ambystoma* may have already been lost.

An amphibian more immediately threatened with complete extermination on Long Island is the northern two-lined salamander (*Eurycea bislineata bislineata*). This slender salamander, averaging only a few inches in length, is adapted to survive in hilly regions with unpolluted spring-fed stream systems. This suitable habitat existed only in the morainal sections of the North Shore on the western half of the island. Fifty or so years ago, the two-lined was abundant within northern Queens County. Naturalist Samuel C. Yeaton, Jr., once collected a thousand specimens in a single day for research use by G. Kingsley Noble, then the curator of herpetology at The American Museum of Natural History. But urbanization brought about the decline of the two-lined during the following decades and it is no longer found in Queens, although some small populations still persist elsewhere on Long Island.

Construction projects, water pollution, and falling water tables all contribute to the plight of the two-lined on Long Island. The remaining populations are almost all restricted to less developed sections of northeastern Nassau County, a low-density area characterized by upper-class estates and comparatively little of the high-density, middle-class sprawl development typical of most of the rest of Nassau.

The easternmost locality known for the species is Smithtown in Suffolk County. Although Smithtown has undergone considerable suburban development during the past couple of decades, at least one two-lined population still exists there. However, two highly localized Smithtown populations known to me appear to have been completely destroyed by human activity during the past several years. Falling water tables may have greatly contributed to the decline of these populations, but other factors could also have been involved. A spring-fed stream system along an entrance road to a county park supported one of the two-lined populations; by expanding a road parallel to the stream, the Suffolk County Department of Parks, Recreation, and Conservation may have dealt the final blow to that population. The other Smithtown group of two-lineds persisted on a hillside until suburban development brought about its demise: a house was built near the last spring hole suitable for salamander reproduction; a backyard garden pool now occupies the spring hole site.

Compared to the other salamanders of Long Island, the red-backed (*Plethodon cinereus cinereus*) is certainly the most urban tolerant, requiring relatively less complicated environmental conditions to complete its life cycle. Its primary advantage over the other salamanders of the island is that it does not need vernal ponds, streams, or other bodies of water for breeding purposes. The red-backed lays its eggs in moist microhabitats provided by fallen rotting logs and other ground litter of upland forests, and the eggs hatch young fully capable of terrestrial existence.

The Fowler's toad (*Bufo woodhousei fowleri*) is probably the most urban tolerant of all the amphibians native to Long Island. It manages to persist where all other species have long disappeared. Key preadaptations enabling the Fowler's toad to survive amidst urbanization include its ability to use almost any body of water as a breeding site, its comparatively short larval period, and its inhabitation of dry upland areas except during the breeding season.

The Fowler's toad still lives throughout most of Long Island; it even persists at many localities within the bounds of the New York City section of the island. Urbanization may actually have enabled the Fowler's toad to increase in abundance, at least on a local basis, through the creation of man-made breeding sites and the elimination of natural competitors and predators. It breeds in park ponds, water-filled sand-mining pits, abandoned reservoir sites, suburban water-recharge basins (sumps), and numerous other seasonal or permanent aquatic areas generally hostile to amphibian survival.

A significant predator of the Fowler's toad is the youngster in pursuit of pets. During June and July, recently transformed toadlets swarm by the thousands along the shores of suburban sumps. The toadlets are often so numerous and concentrated that one cannot walk without accidentally crushing many underfoot. Young suburbanites take many that will languish and die in captivity. Yet the Fowler's toad seems to be able to hold its own.

Contrasting with the successful history of the Fowler's toad on Long Island is that of the gnomish eastern spadefoot (*Scaphiopus holbrooki*). The spadefoot is believed to be de-

Children in search of pets are significant predators of the eastern box turtle, top left. This activity is illegal in New York State, but lack of enforcement has caused the deterioration of the species on Long Island. Concrete covering the sandy soil in which it burrows and vernal pools drying up because of lowered water tables are among the probable causes for the decline of the eastern spadefoot toad, left, on the western half of Long Island.

scended from toads that evolved in desert conditions of the southwestern United States. Under xeric conditions, selection pressures favor an amphibian that remains inactive during long, desiccating dry spells and fully utilizes brief periods of heavy rains. Eventually, *Scaphiopus* stock moved eastward. Although much moister conditions prevailed in the east, the spadefoot retained its breeding habits—remaining dormant for long periods and utilizing breeding sites only during heavy rains. The sandy soil of Long Island provided the spadefoot with an excellent habitat, and it apparently thrived throughout most of the island until the advent of urbanization several decades ago. Now it is rare on the west end, and the only known significant populations survive in wilder sections of Suffolk County.

Why has the spadefoot failed to meet the challenge of urbanization? Much of the sandy soil in which it burrows continues to disappear under concrete and macadam. The seasonal pools preferred for breeding become dry year-round as water tables fall. Also, the spadefoot may be unable to perpetuate itself on urban tracts possessing seemingly suitable soil and breeding conditions but lacking the acreage necessary to sustain viable populations. Ecologist Paul G. Pearson has presented evidence that the spadefoot displays territorial behavior. A tract might have enough resources other than land space to permit the spadefoot to maintain a necessary minimum population level, but the intrinsic behavior of this amphibian might prevent maximum over-all utilization of these resources through the territorial spacing of individuals. Thus, the Fowler's toad may be more successful than the spadefoot largely because its population densities are not influenced by intraspecific territorial behavior.

Like amphibians, reptiles show a wide diversity of urbanization tolerances. One of the most tolerant species on the west end is the northern brown snake (*Storeria dekayi dekayi*). Averaging a foot or less in length, this inoffensive reptile may be regarded as the snake most suitably preadapted for survival in a metropolitan center. The northern brown is one of the three or so snake species persisting amidst the urban turmoil of the New York City end of Long Island and may very well be the most abundant serpent there. Littered lots and neglected parks provide the snake with habitats too small and hostile for most other herpetozoans.

Despite its ability to persevere in the city, the brown snake has not fared well in much of suburbia to the east. A large percentage of the high-density suburban developments in Nassau County now exist where a great wilderness—the Hempstead Plains—once stood. The Plains, covering tens of thousands of acres, has been almost completely obliterated by the tacky developments characteristic of the post-World War II housing boom. Remaining are no more than a few hundred acres even remotely resembling the primal grandeur of the Plains. Sketchy data published by Long Island natural historians indicate that the brown snake had been fairly common on the Plains, but the tide of suburbanization has reduced it to a condition of extreme rarity, if not total absence, in this area. I have done much field work in the Plains for more than a decade and have failed to find a single brown snake.

Why has the brown snake done so well within the limits of New York City and so poorly in a less urbanized suburban area? A minimum number of individuals may be needed for a population of the brown snake to perpetuate itself, and the densities of the predevelopment populations were perhaps greater within the deciduous forest that covered much of the land in the city and thinner within the grassland that dominated the Hempstead Plains. Thus, a brown snake population might have been able to survive in an enclave of just a few natural acres around which urban development mushroomed in the city, but not in a similar-sized site surrounded by the suburban sprawl that has engulfed the Plains. Also, vacant city lots are usually more cluttered with the dumpings of humanity than are the suburbs. The presence of this artificial shelter may be a necessity for the brown snake to persist on small acreages, and the comparative lack of it on a suburban site may preclude the existence of the northern brown there.

The brown snake seems to be gone from the Hempstead area, but the eastern garter snake (*Thamnophis sirtalis sirtalis*) still endures there. Although the northern brown may give the eastern garter some competition for the title of "most urban-tolerant snake" on Long Island's west end, there can be no doubt that the eastern garter more truly deserves this designation when the island is considered as a whole. The generalized habits of the garter snake undoubtedly permit it to persist where the environmental requirements of other species are no longer present.

The semiaquatic eastern ribbon snake (*Thamnophis sauritus sauritus*) is a more specialized relative of the garter snake. A comparison of ecological factors in the life cycles of the two species reveals why the garter succeeds better than the ribbon amidst urban development. Although sometimes found in semiaquatic environs, the garter snake is not restricted to habitats of this type; the ribbon snake, however, is virtually restricted to semiaquatic habitats. Swamplands are among the habitats most vulnerable to development and are often the first to disappear during the urbanization process. The garter feeds on a wide variety of terrestrial vertebrate and invertebrate animals, including earthworms. The ribbon, generally a fish and amphibian feeder, does not have such broad feeding habits and may be selectively disfavored. Clearly, urbanization favors the generalized species.

The damming of streams for recreational use, reservoirs, and other human purposes has probably resulted in the creation of more deep-water ponds than naturally existed on Long Island. This has resulted in the availability of more suitable habitats to such aquatic chelonians as the eastern painted turtle (*Chrysemys picta*

Although a woodland dweller, the marbled salamander must breed in ponds, and the young are not able to walk on land until eight or nine months old. Fewer suitable ponds have caused its decline.

E. R. Degginger

picta) and common snapping turtle (*Chelydra serpentina serpentina*). Both the beautifully marked painted turtle and the large snapper inhabit nearly all of the permanent ponds of Nassau and Suffolk counties and thrive despite the pursuits of turtle collectors. But semiaquatic species, most notably the spotted turtle (*Clemmys guttata*), have declined as their swampland habitats along stream courses were submerged under the waters backing up behind newly formed dams. The colorful spotted is less wary than the painted and more in demand by turtle fanciers; a price of twenty dollars for a single spotted is not unusual. A few small populations of the spotted may still exist on the west end, but, without doubt, this is an urban-intolerant species.

One of the animals most adversely affected by the activities of pet-hunting youngsters is the terrestrial eastern box turtle (*Terrapene carolina carolina*). Even where woodland tracts of seemingly suitable box turtle habitat remain, this reptile is often rare or absent. This is especially true for county and state parklands in which ground-level nature trails are maintained.

The idea of bringing nature to the public via a trail system has usually been done without any ecologically sound planning. Often the paths are designed primarily with the arboreal fauna—most specifically the birds—in mind. Of course, tree-dwelling birds, living well above the reaches of vandals or ecologically naïve park visitors, are rarely ever removed or disturbed. For ground-residing animals, however, such paths can be disastrous. Wherever the home range of a terrestrial animal overlaps a ground-level path, an encounter with a park visitor can be expected sooner or later. If the animal is a box turtle and the visitor a pet-seeking youngster or adult, it may well be anticipated that the park will be missing a box turtle. (Collecting box turtles is illegal in New York State, but the law is not effectively enforced.)

If the trails are numerous and the human traffic great, one can be certain that, in time, a park will become herpetologically impoverished. Unfortunately, this is usually the case in Long Island parks. In evaluating a park, park agencies should adopt a policy of requiring a thorough biological survey based on modern ecological theory. And any trail system (an elevated boardwalk type if necessary) should permit maximum public access to the park but with minimum possible impact on ground-level plants and animals.

The natural and unnatural history of the amphibians and reptiles of Long Island reveals that some species are tolerant of urbanization pressures but that, sooner or later, others will succumb to the unnatural forces unless we act wisely.

The notion of "endangered species" should be abandoned in favor of the concept of "endangered local populations" or "endangered local communities." Although Long Island possesses no endemic species of herpetozoans, preliminary studies indicate that the island may possess populations of at least several species with endemic genetic traits.

Many species will continue to survive despite the onslaught of urbanization. Even among these urban-tolerant species, however, there may exist genotypes that will disappear under the unnatural selection pressures wrought by man. If we are to save this genetic heritage, we must do so based on an understanding of the morphological and behavioral preadaptations involved and on our knowledge of the historical effects of urbanization on these animals in areas such as Long Island. □

Cerebral Clues

by Leonard Radinsky

Fossil braincases hold evidence of the behavior of ancient animals

Fossils are indispensable to the study of ancient life. A jaw—even a tooth—can suggest what kinds of food an animal ate. A leg bone can indicate running ability; a skull, the size of the brain. Unfortunately, actual brains are never part of the fossil record since neural tissue is extremely sensitive and decomposes rapidly after death. Yet, by using information from the work of neurophysiologists, paleontologists can study fossilized brain anatomy and learn about the behavior of animals that died millions of years ago.

The main senses—visual, auditory, tactile, and olfactory—have their inputs represented on the cerebral cortex, or surface of the brain. Furthermore, in many species, usually of large-brained mammals, the various functional areas of the cerebral cortex—visual, auditory, tactile, and motor—are bounded by grooves. To determine the location of these areas in living mammals, scientists place fine electrodes in the cerebral cortex, then stimulate those parts of the body that receive sensory information (sensory receptors), such as eyes, ears, and fingertips. In this way, they can see which parts of the cerebral cortex are activated by a given stimulus.

Flashing a light on part of the retina of the eye, for example, will result in an electrical impulse in part of the visual cortex. Or the process can work the other way: stimulating a point on the motor cortex of the brain and noting which muscles of the body contract enable one to map the motor cortex. By extrapolating from the brains of mapped species, using the pattern of grooves as a guide, paleontologists can predict where the major functional areas are located on the brains of unmapped species.

Behavioral specializations may show up as unusual enlargements or reductions in size of a part of the brain devoted to a given sensory input. Coatimundis, for example, relatives of raccoons, have unusually sensitive snouts, which they use to probe under leaf litter for food. Consequently, the area of the brain that receives tactile information from the skin of the snout is enlarged. Reductions in size of a part of the brain are revealing too. Porpoises and toothed whales have lost the sense of smell, a characteristic that is reflected in the absence of olfactory bulbs in their brains.

Raccoons provide a striking example of the correlation between behavioral specialization and size of a functional area of the brain. Since raccoons use their hands to forage for food, particularly in places where vision and olfaction are limited, such as in shallow water, the skin of their hands is quite sensitive.

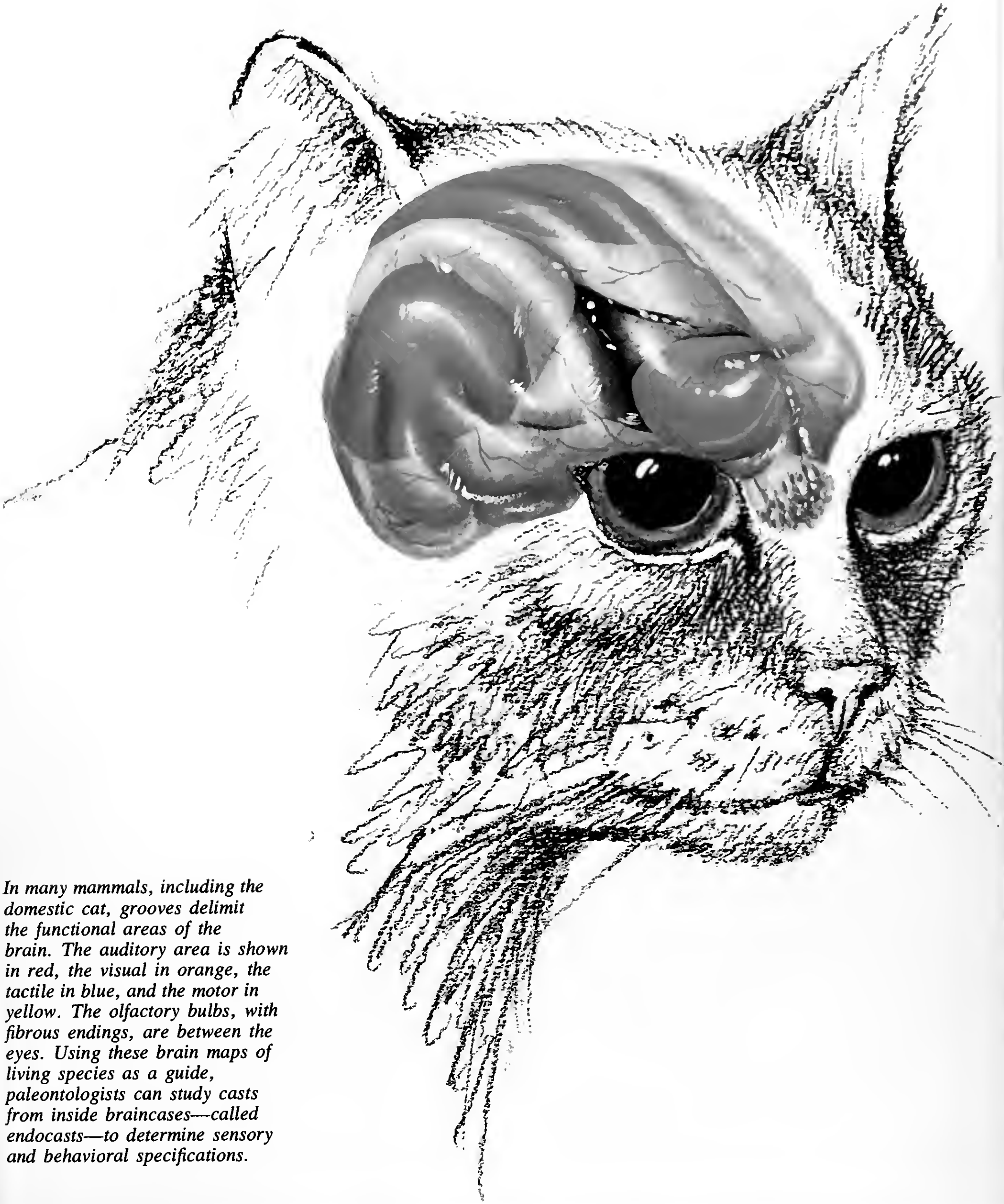
In captivity, raccoons often take a food object and, before eating it, handle it underwater. Although we call this behavior "washing," its function is probably to soften the skin of the hands, thereby increasing its sensitivity. W. I. Welker and his colleagues at the University of Wisconsin mapped the tactile receiving area of the brains of raccoons and discovered a great enlargement of the area receiving touch information from the hands. Not only is that area enlarged, it is also delimited by grooves; even the projections of the individual digits are bounded by grooves, a highly unusual degree of specialization.

But what of extinct species? The above examples show how sensory and behavioral specializations may be reflected in the brain surfaces of living animals; the same relationship between form and function provides an opportunity to interpret the behavior of extinct species. In some vertebrates, particularly birds and mammals, the brain fills the braincase and, during life, molds the inner surface of the braincase to its form. When the animal dies, the brain itself decomposes rapidly, but the bone of the braincase preserves an imprint of the brain's surface. A cast of the inside of the braincase, called an endocranial cast, or endocast, reproduces the external configuration of the living brain once housed there. Since many details of surface morphology, including the pattern of convolutions and imprints of blood vessels and nerve roots, are usually preserved, endocasts can provide a fossil record of brain morphology.

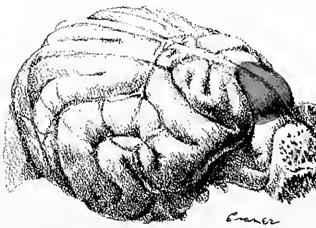
Although this technique works well with many animals, there are some exceptions. In some of the largest-brained mammals, such as elephants, whales, porpoises, and the great apes and humans, surface details are blurred on endocasts and only the gross size and shape of the brain are reproduced. And in the lower vertebrates—fishes, amphibians, and reptiles—the braincase usually does not enclose the brain snugly. Since there is a considerable amount of connective tissue and fluid around the brain, endocasts of those animals usually do not accurately reproduce the shape of the brain.

Endocasts are made in two ways. Some fossil skulls are filled with a hard stone matrix; by stripping away the bone, paleontologists can expose the natural stone endocast. Sometimes this happens in the field through normal processes. of erosion. To make an artificial endocast, the inside of a cleaned-out braincase is coated with liquid latex. After curing the

illustrations by Douglas Cramer



In many mammals, including the domestic cat, grooves delimit the functional areas of the brain. The auditory area is shown in red, the visual in orange, the tactile in blue, and the motor in yellow. The olfactory bulbs, with fibrous endings, are between the eyes. Using these brain maps of living species as a guide, paleontologists can study casts from inside braincases—called endocasts—to determine sensory and behavioral specifications.



The evolution of the canid brain shows the emergence of social behavior. Canids that live in packs have an enlarged portion of the frontal lobe that appears to inhibit the "fight or flight" response of solitary animals. The earliest canid endocast, above, from 30 million years ago, lacks this enlargement; it begins to appear in a 15-million-year-old cast, top right, and is greatly expanded in the modern jackal, right.

latex to make it tough and elastic, it is finally collapsed and the endocast is pulled out through the foramen magnum (the large opening at the back of the skull for the spinal cord). Because it is elastic, the endocast will pop back into its original shape, thus providing a cast of the inside of the braincase without requiring sectioning or otherwise damaging the skull. This makes it possible to use museum collections of recent mammal skulls to build up a reference collection of contemporary mammal endocasts and to see what the outside of the brain looks like in rare mammals for which actual brains are not available.

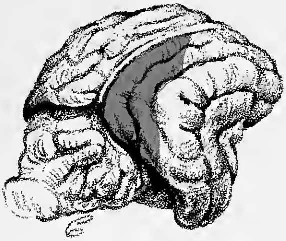
By applying cortical maps made by neurophysiologists to fossil endocasts prepared by paleontologists, we can gain insights into behavioral specializations of long-dead animals. Unfortunately, there is no fossil record of raccoon brains to tell us when they evolved sensitive hands and washing and foraging behavior using their hands, but a comparable tactile specialization occurs in another group of carnivores—otters—for which there is a relevant fossil record. Although no one has yet mapped living otter brains in the lab, their pattern of convolutions is similar enough to that of mapped carnivores, such as dogs, cats, and raccoons, to allow interpretation of their functional areas when examining endocasts.

The common river otter has a greatly expanded cortical area for tactile information from the face. Since these otters have unusually long, thick, and numerous facial vibrissae ("whiskers"), it seems likely that the cortical enlargement is for vibrissal input. Other aquatic carnivores, such as seals and sea lions, also have elaborate vibrissae and also appear to have an enlarged cortical area for vibrissal input. Presumably, this specialization evolved to detect vibrations underwater, perhaps to make up for reduced sight and smell—senses that help land carnivores find prey.

A fossil endocast of a 10-million-year-old ancestor of the river otter, although incomplete, shows expansion of the same cortical area that is expanded in living river otters. The degree of expansion is not as extreme as in the living species, but it is great enough to indicate that at least 10 million years ago ancestors of river otters had sensitive whiskers.

There are even older endocasts from a genus related, but not directly ancestral, to modern otters. Twenty-five-million-year-old endocasts of *Potamotherium*, an early, aquatically specialized carnivore, show expansion of the same cortical area, suggesting that sensitive vibrissae had evolved in *Potamotherium* that far back. Presumably, they evolved in response to the same selective pressures—the need in an aquatic carnivore to compensate for reduced visual and olfactory abilities underwater—that were responsible for the adaptation in modern otters. Because its brain was relatively primitive in other respects, the occurrence of a tactile specialization in *Potamotherium* is particularly interesting. This combination of primitive and advanced features in the same species results from mosaic evolution, wherein different body parts evolve at different rates.

Other living otters, such as the clawless otters of Africa and Asia and the sea otter of the North Pacific, use their hands for foraging for food in water. Not surprisingly, they have enlargements of cortical areas for tactile inputs from the hand. A fossil endocast of a 7-million-year-old ancestor of the African clawless otter re-



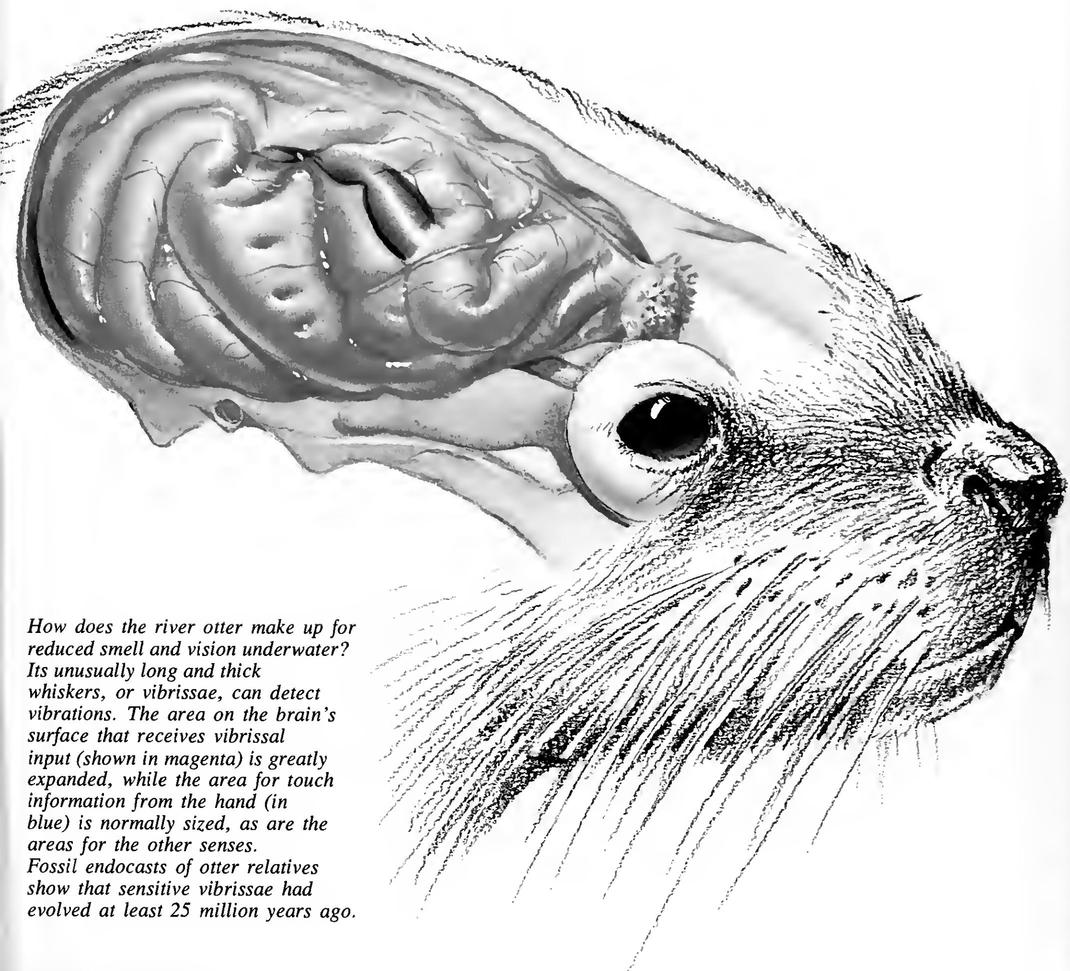
An endocast from a 15,000-year-old saber-toothed cat, right, shows an expanded visual cortex, proportionately larger than that in the modern cheetah, above. Since this saber-tooth also had unusually long legs, it probably inhabited open country, where its visual acuity would have helped in detection of prey at a distance.

veals an expanded hand projection area, indicating that sensitive hands and the correlated foraging behavior had evolved in that lineage at least that far back in time.

The recent discovery of a fossil cat shows another sensory specialization, an elaboration in the visual system. Although the fossil record of felid brains goes back 35 million years, a survey of endocasts of fifteen extinct genera and of twenty-seven modern species turned up only one with unusual cerebral characteristics. *Dinobastis,* a long-legged, saber-toothed cat, lived in North America at the end of the last Ice Age, about 15,000 years ago. The two endocasts known for this genus, one from Texas and one from Alaska, show an expansion of cortex at the back of the cerebrum. When we compared these with cortical maps of modern cat and lion brains, we found that the expanded area of the *Dinobastis* brain corresponds to that receiving input from the central visual field of the retina.

The enlargement suggests that *Dinobastis* had different visual abilities—or processed visual information in a different way—from other felids. *Dinobastis* also had unusually long legs, suggesting that it was an open-country cat; perhaps the visual specialization was for long-distance detection of prey.

Even social behavior can be correlated with a neuroanatomical feature. All living canids with pack social structure, such as wolves, African hunting dogs, and Indian dholes, show an enlargement of the prorean gyrus, which is part of the frontal lobe. The same part of the frontal lobe is also enlarged in some canids that do not have pack social structure, such as coyotes and jackals, but at least in the case of coyotes, it seems that relatively recent disruption of their habitat, including pressure from humans, has forced them into a more solitary existence. Of the living canids that lack the enlarged prorean gyrus—mainly the different kinds of



How does the river otter make up for reduced smell and vision underwater? Its unusually long and thick whiskers, or vibrissae, can detect vibrations. The area on the brain's surface that receives vibrissal input (shown in magenta) is greatly expanded, while the area for touch information from the hand (in blue) is normally sized, as are the areas for the other senses. Fossil endocasts of otter relatives show that sensitive vibrissae had evolved at least 25 million years ago.

The raccoon's foraging style is reflected in its brain: the area that receives tactile information from the hands is not only greatly enlarged, it is also bounded by grooves. Even the projections of its individual fingers are delimited. Raccoons often handle food objects underwater, not for hygienic purposes, but apparently to increase the sensitivity of their hands by softening the skin.

foxes and their relatives—none show complex social structure.

The prorean gyrus of the frontal lobe functions in inhibiting primitive behavioral responses. Such inhibition would be necessary for the maintenance of complex social structures, such as wolf packs. Each individual has a position in the social hierarchy, and for smooth interaction between members of the pack, "fight or flight" responses must be dampened.

The fossil record of canid brains, which goes back about 30 million years, reveals that the prorean gyrus expanded beyond the modern fox condition probably within the past 5 million years. Thus, pack social structure, with its advantages in hunting, is a relatively recent development in canid evolutionary history. Now it would be interesting to examine the fossil record of the presumed prey species and competitors of living pack canids to see if there were changes, such as extinctions or the appearance of new adaptations, that occurred when canids developed pack social structure.

The examples discussed so far have been of carnivores, most of which have the convoluted brains that make behavioral inferences possible. Most members of our own order, the primates, also have convoluted brains, but the fossil record of primate brains is scanty because the skulls are rarely preserved intact as fossils. Also, primates are usually not very numerous elements of a fauna, and they usually live in forested areas where they are not likely to be preserved in sediments. Despite the sparse record, primate endocasts do reveal some important points about primate evolutionary history.

The oldest known primate endocast is from *Tetonius,* a small, large-eyed animal that lived in Wyoming about 55 million years ago. This was at the beginning of the second great evolutionary radiation of primates (the first occurred about 10 million years earlier), a time when several major groups of lower primates were emerging. An endocast from such a time is of particular interest for the light it may shed on the adaptations responsible for the radiation.

The brain of *Tetonius* differed from the primitive mammalian condition (best represented today by brains of some shrews and hedgehogs, known as basal insectivores) in having reduced olfactory bulbs and expanded visual cortex. Compared to modern primates, *Tetonius* had larger olfactory bulbs and a relatively smaller frontal lobe. In relative size (compared to body weight), the brain of *Tetonius* was intermediate between those of basal insectivores and modern primates. The same features that distinguish the brain of *Tetonius* from the primitive mammalian condition also apply to other early primate brains from 50, 45, and 35 million years ago. This suggests that at least for the second primate radiation, increased reliance on vision and decreased importance of olfaction were important adaptations. The significance of the increase in relative brain size is not clear, and whether or not similar adaptations characterized the earliest primates, 65 million years ago, also remains to be seen.

The third major wave of primate evolutionary radiations, marked by the first appearance of higher primates (today, these are represented by New and Old World monkeys, apes, and humans), began about 35 to 40 million years ago. Endocasts from *Dolichocebus*, one of the earliest New World monkeys; *Aegyptopithecus*, one of the oldest apes; and *Apidium*, a possible early relative of Old World monkeys, dated about 27 million years ago, suggest that the earliest higher primates had relatively more visual cortex and relatively smaller olfactory bulbs than do lower primates (represented today by lemurs, lorises, and galagos). Thus, these animals relied less on smell and were increasingly dependent on vision, adaptations that may have been among those responsible for the emergence of higher primates.

Higher primates also differ from lower primates in having relatively larger brains, but it is not clear from the fossil record when that was attained. Of the three earliest primate endocasts, we can estimate frontal lobe size only in *Aegyptopithecus*. In that form, as in the early lower primates, the frontal lobe appears to have been relatively small compared to its modern condition. In fact, higher and lower primates did not evolve brains that appear "modern" until about 18 million years ago.

Given our particular interest in our own species and our unique behavioral abilities, such as speech and abstract reasoning, it would be interesting to be able to trace the evolution of those abilities in the fossil record. Unfortunately, endocasts are less useful than other aspects of our fossil record, such as teeth, bones, and artifacts, for such purposes.

First, humans are among the small minority of mammals in which, owing to large brain size, details of brain morphology are not reproduced on endocasts. Little more than gross size and shape of the brains of our immediate ancestors can be interpreted from the fossil record. Second, with the partial exception of speech, uniquely human abilities are not neatly localized in the cerebral cortex. Even if every groove were faithfully reproduced on fossil hominid endocasts, one could not interpret much about behavior from them.

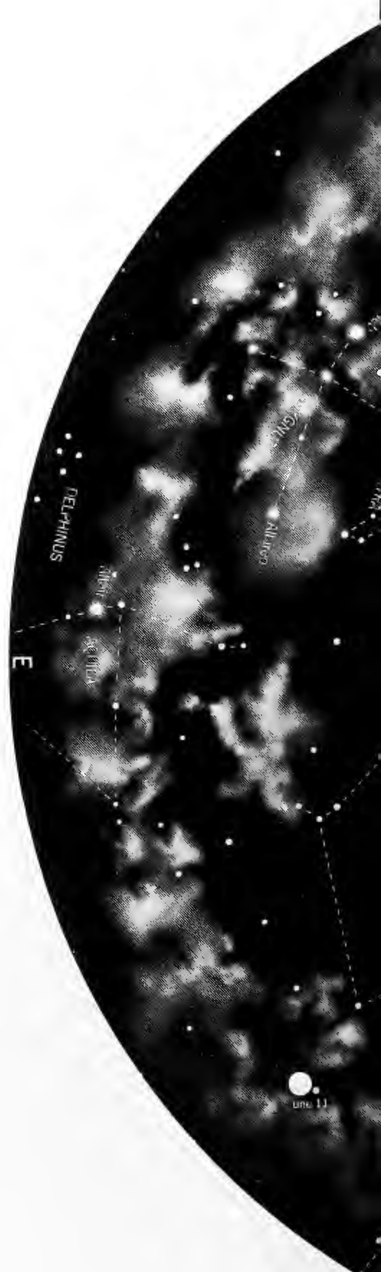
The size of fossil human endocasts, however, is the subject of much study. One of the few features in which modern human brains differ from those of other primates is size, both in absolute terms and relative to body weight. In fact, our brains average about three to three and a half times as large as one would expect in a higher primate of our body weight. How tempting it is to ascribe great significance to such measurable differences, but in the case of brain size, there is little hard evidence as to what it means. Certainly, within modern humans there is great variation in normal brain size, and no known relationship between brain size and mental or other abilities.

Hominid endocasts 2 to 3 million years old are intermediate in relative size between those of modern humans and those of other higher primates, indicating that our relatively large brain size appeared quite recently. One of the fascinating goals for students of human evolution is to decipher the significance of this.

The union of paleontology and neurophysiology is an exciting one. Endocasts of hundreds of fossil mammals remain to be studied and interpreted. The information derived from such studies not only increases our understanding of ancient life but also helps us to understand the pathways to modern life. □

Celestial Events

by Thomas D. Nicholson



Sun and Moon When May begins, the sun is in the constellation Aries; it moves into the stars of Taurus about the 14th where it remains past mid-June. Meantime, it continues moving north of the equatorial plane, but more slowly. About 19 degrees north on May 1, it moves up only 3 more degrees by June 1, and is moving almost parallel to the equator by mid-June.

The early crescent moon will appear in the evening of about the 1st or 2nd in both May and June. Moonlight dominates the evening sky for the first two weeks of both months, and the morning sky from mid-month to about a week before month's end. Phases in May are first-quarter on the 7th, full on the 13th, last-quarter on the 20th, new on the 28th; in June, first-quarter on the 5th, full on the 11th, last-quarter on the 19th, and new on the 27th.

Stars and Planets Spring stars are overhead and high in the south this month, with winter stars all but gone in the west and summer stars coming up in the east in early evening. One of the regular surprises on an early May evening is to see two bright stars, to the left and right of north, low in the sky. The one on the left is Capella, in Auriga, a bright winter star that can still be seen because it is so far north. The one on the right is Vega, in Lyra, a bright summer star that is so far north we can see it quite early in the year.

Two planets are included on our Star Map this month. Mars and Saturn, evening stars, are very low in the west at the time for which the map was prepared. You may be able to see them from dusk for at least an hour or two, but they will be clearer and higher earlier in May than later on. The other planets, Mercury, Venus, and Jupiter, are all morning stars. Only Jupiter is favorably placed, however, rising in the east early enough to be visible in the morning twilight.

May 20: Mercury passes between earth and sun today (inferior conjunction). It now leaves the evening sky and becomes a morning star.

May 24: The moon is at apogee, farthest from earth.

May 26–27: Just before midnight on the 26th, the moon passes so close to Jupiter that it covers the planet (an occultation) over Europe and Asia. Jupiter and the crescent moon, still quite close, make a pretty sight in the dawn sky of the 27th, with Jupiter hanging right below the lower tip of the moon's crescent.

June 1: Mercury, having passed between earth and sun, resumes its direct (easterly) motion.

June 2: Saturn and Mars are to the north of the early crescent moon: Saturn, to the right, is the brighter planet; Mars above the moon and closer to it.

June 7: The bright star near the moon is Spica, in Virgo. The moon moves closer to the star until midnight, then separates to its left.

June 9: The moon is at perigee, nearest earth.

June 15: Mercury is at its greatest westerly elongation, best placed as a morning star but low, even at sunrise.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 10:25 P.M. on May 15; 9:20 P.M. on May 31; and 8:20 P.M. on June 15; but it can be used for an hour before and after those times.

Helmut Wimmer

Exploding Stars

Two new additions to the already observed population of novae have aroused much scientific interest

Two novae, or exploding stars, were discovered last August. One, Nova Cygni, was easily visible to the unaided eye and was the brightest exploding star seen from earth since 1942. Allowing for the dimming of the star's light owing to its great distance and the absorbing effect of interstellar dust clouds, Nova Cygni was, in fact, first in true brightness of the more than 150 novae that have been observed since the seventeenth century. The other exploding star, known as A0620-00, or Nova Monocerotis, was much fainter and never became visible without telescopic aid. Nevertheless, despite significant findings concerning Nova Cygni, it is the dimmer nova that attracted the greatest scientific interest. Measurements by British and American satellites revealed that A0620-00 was a powerful source of X-ray radiation, whereas Nova Cygni (like other, previously scanned novae) generated no detectable X-rays. That distinction accounts for the differing interest.

Whether they recognized it as a celestial event or not, many thousands, perhaps millions, of persons probably saw Nova Cygni during the few days in late August and early September when it was prominent in the evening sky. The star reached a peak brightness comparable to the brightest stars of the Big Dipper and was favorably located for observation, close to the Northern Cross, a familiar star pattern in the constellation Cygnus.

The first official report of Nova Cygni, which came from Japan, was received in this country late on Friday, August 29, the eve of Labor Day weekend. I first learned of the event the next morning in a phone call from a NASA astronomer who happened to be visiting on Kitt Peak in Arizona and had already seen the star. Later, a colleague called from Toronto with the news that the star was readily visible from that city. Where I lived, however, near Washington, D.C., cloudy weather persisted throughout the long holiday weekend, and by the time the skies had cleared, the nova had faded. I had to use field glasses to identify it with certainty, although it would still have been visible to the eye from dark rural sites. According to Luigi Jacchia, an expert on variable stars at the Center for Astrophysics, in Cambridge, Massachusetts, this sudden drop in intensity shortly after Nova Cygni reached maximum brightness may have been the fastest such decline on record.

Nova means "new." Astronomers originally used the word to signify a new star, one that appeared where none was seen before. We now know that the phenomenon is due to the eruption of a very dim star, typically one at least 25,000 times fainter than the novae observed during past decades, and thus visible only on telescopic photographs. For centuries before Western scientists recognized these events, Oriental astronomers took careful note of them. The Chinese lumped them together with supernovae (much greater and rarer stellar explosions) and bright comets as so-called guest stars, or temporary visitors in the heavens. Like the Star of Bethlehem, novae were regarded as omens. One guest star seen in A.D. 1230 was evidently taken as a good omen and is said to have inspired a "general amnesty in Japan."

The modern practice when a nova is discovered is to examine the corresponding photographs from the National Geographic Society-Palomar Observatory Sky Survey, the basic professional star atlas, in order to locate the "prenova," or unerupted star. But when an astronomer at the Southern Station of Moscow's Sternberg Astronomical Institute examined the Palomar Sky Survey photographs taken in 1952 of the Nova Cygni region, he found no star at that

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location. On the other hand, four Soviet photographs made by professional astronomers between the fifth and twenty-fifth of August 1975, which happen to include the region, do show a dim star at the site of the nova. In addition, photo sequences taken with meteor patrol cameras in Los Angeles, California, and Leader, Saskatchewan, just prior to the August 29 discovery and subsequently analyzed, show a typical fast eruption of the nova.

From this information we can conclude that between 1952, the year of the Sky Survey photos, and August 5, 1975, the date of the first Soviet photograph, the prenova had a preliminary eruption, or possibly just a gradual brightening, that increased its intensity by at least a factor of 100. Then, a day or so before the star was

Nova Cygni faded rapidly from its peak brightness, as shown in this series of photographs taken in Atlanta, Georgia, with a 36-inch telescope. The first photograph was made on August 31, 1975; the second on September 2; the third on September 9; and the last on October 11.

spotted in Japan in late August, the major eruption, amounting to a factor of 400,000 in brightness, occurred. Based on this interpretation, Jacchia has proposed a novel explanation for Nova Cygni.

According to the leading theory of novae, the explosions take place in binary star systems, which consist of two stars—one a white dwarf, the other a red star—in orbit around a common center of mass. The white dwarf is a hot and highly compact star, about the size of the earth, but with an intense gravitational field. (The first known white dwarf, Sirius B, was described in "Red, White, and Mysterious," *Natural History*, August-September 1975.) The other member of the nova binary, the red star, is larger and cooler.

The planets that orbit our sun are not affected by the gravity of other stars, since no other star is close enough to exert a noticeable force. In a binary star system, however, the two stars may be quite close together, leading to a more complex gravitational situation. In analyzing that situation, astronomers postulate a mathematically defined region around each star, called the "Roche lobe" after a nineteenth-century French astronomer. The curved surface of the lobe represents the effective limit of each star's gravitational dominance over nearby matter. The Roche lobes of binary stars touch each other and matter that is released or ejected from one star and passes through the contact point into the adjacent Roche lobe of the companion star can stream down onto the second star.

In the case of a nova binary star system, astrophysicists believe that the red star grows so large that its outermost region expands through its own Roche lobe. The gaseous matter thus emitted is lost to the star and some of it passes through the contact point with its companion's Roche lobe and falls onto the surface of the white dwarf. The white dwarf is now coated with a surface layer of unstable material, heated by its fall, and nuclear reactions generated in that layer cause the explosion. The exploded material flies out from the white dwarf at high velocity, forming a rapidly expanding nebula, or cloud of gas and dust. It is the light from this nebula that we observe on earth as the nova, and as the nebula dissipates into space, the nova fades away. Presumably, material continues to stream down from the red star onto the white dwarf almost indefinitely, building up new unstable layers that will also explode. The interval between these subsequent explosions may be 100 centuries, although similar, but much less violent, outbursts occur in certain other stars, known as "recurrent novae," at intervals of only a few dozen years.

Judged by its total increase in brightness, Nova Cygni has been described as the greatest nova eruption yet seen. The total increase, including the preliminary and the major eruptions, amounted to at least a factor of 40 million (100 × 400,000). This is unique for a nova, but if we consider the two observed stages in the outburst separately, the second stage, amounting to a factor of 400,000, while large, is no greater than the increase in brightness of some previous novae. Jacchia's suggestion is that Nova Cygni is a virgin nova, one undergoing its very first eruption, and that the virgin outburst occurs in two stages. The initial step in the process is a modest increase in brightness, such as the 100-fold or more increase involved in the first stage of the Nova Cygni event, as adduced from the Soviet photographs. This stage occurs only once in the history of the star. The second stage is a large eruption, similar to that recorded in Japan and by the meteor cameras. Subsequent explosions roughly equal in brightness to the second stage, but not as great as the product of the two stages, may follow at widely separated intervals.

If Jacchia's proposal is true, nearly all of the novae seen in the past were probably old ones, long past the virgin stage, and the next outburst of Nova Cygni, which may take place many centuries hence, may resemble the explosions of past novae. The coming Nova Cygni outburst would thus amount to a factor of several hundred thousand or less, rather than the over 40 million times increase witnessed in 1975. Based on this theory, as Nova Cygni continues to fade this year, it should level off at about the brightness it had in early August 1975, when photographed by the Soviet astronomers. If the theory is wrong, the star will become much fainter, perhaps dropping again below the limiting sensitivity of the Palomar Sky Survey.

The other August nova, A0620-00, was discovered on the third of the month by scientists at the University of Leicester in England. They used an

X-ray sky survey instrument carried on a British satellite. At the time, the nova seemed to be just another of the so-called transient X-ray sources found by rocket and satellite experimenters since 1967. These sources appear briefly, then fade away over periods of weeks or months. Little was known about them prior to 1975. Optical astronomers were unable to locate them telescopically since the positional information available from rocket and satellite instruments was relatively crude. But in May 1975, NASA launched an astronomy satellite with equipment designed by Massachusetts Institute of Technology physicists to determine more precise positions for X-ray sources and with the capability of reorienting itself rapidly in space upon command from the ground.

On August 7, when the X-ray intensity of the nova had exceeded that of the Crab nebula and was still increasing, news of the British discovery was cabled to the United States, and on the next day the NASA satellite, *SAS-3*, began observing the source. One week later, when A0620-00 had become the brightest X-ray emitter in the heavens, an accurate position for it, as determined by *SAS-3*, was announced to the optical astronomers. On the next day, August 16, a dim blue star was discovered at that location by two Dartmouth College astronomers working at the brand-new McGraw-Hill Observatory in Arizona. The blue star was also found on the Palomar Sky Survey photographs of the region, which revealed that it had previously been more than 3,000 times fainter. Thus, an optical outburst was accompanying the X-ray event.

The Dartmouth discovery meant that the newest, most powerful X-ray source in the sky could be accurately located and examined with any suitable ground-based telescope. The details of the object's precise location placed A0620-00 in the constellation Monoceros, the Unicorn, just east of the border of Orion. Only a few days before the Dartmouth find, radio emissions from the object's direction were detected with the 1,000-foot radio telescope at Arecibo, Puerto Rico, and by smaller radio telescopes at Green Bank, West Virginia, and Jodrell Bank, England. Now, thanks to the accurate position determined for A0620-00, it was possible to examine the exploding star with the new four-meter optical telescope at Kitt

Peak National Observatory in Arizona and the equal-sized Anglo-Australian telescope in Australia, as well as with a host of other optical, radio, and infrared instruments on Kitt Peak and in France, Chile, South Africa, the Canary Islands, and elsewhere.

A second American satellite investigated the X-ray spectrum of A0620-00 and a Dutch spacecraft measured its ultraviolet radiation. In September, Soviet cosmonauts aboard the orbiting *Salyut-4* space station measured its intensity at six X-ray wavelengths. The most important study of all, however, may have been done at Harvard College Observatory without the use of any instruments whatsoever!

Harvard astronomer Lola J. Eachus decided to search through the observatory's "plate stacks," that is, the collection of old sky patrol photographs made on glass plates with small telescopes. Her objective was to determine whether A0620-00 might have erupted before. As recounted by a colleague who supervises the sky patrol, Eachus had examined without success about 500 photographs of the Monoceros region made since 1898 when, in the last small batch, she found a plate from 1917 that clearly revealed an eruption. Eventually, three other patrol plates and one made with a larger telescope were found that traced the eruption and its decline from early November 1917 to February 1918.

Based on this proof of the prior outburst of A0620-00, the Harvard astronomers have proposed that the source is actually a recurrent nova of the type mentioned earlier. By analogy with the known properties of such stars, they have deduced that A0620-00 must lie more than 15,000 light-years beyond the known limits of our galaxy, alone in adjacent intergalactic space.

If A0620-00 were as distant as suggested by the Harvard group, then its energy output must be truly astronomical and, accordingly, extremely difficult to explain. Furthermore, since all stars are formed in galaxies, I wonder how this one got so far out of our galaxy, where it must have originated? A variety of alternative models have been proposed to account for the nature of A0620-00.

Any theory must explain why, if A0620-00 is a nova or novalike object, it produced intense X-rays, while Nova Cygni, optically far brighter, remained undetected de-

spite searches with X-ray telescopes on various satellites. Two MIT physicists suggest that the X-rays were generated when the material ejected in the nova explosion collided with—and heated—surrounding circumstellar gas, which might remain from a prior outburst or might simply be gas lost through the Roche lobe of a red star if A0620-00 is a binary system like other novae. The trouble with this theory is that it implies the existence of certain spectral lines at X-ray wavelengths that were searched for in vain by the British satellite.

A second hypothesis, offered by three NASA astronomers, assigns the optical emission of A0620-00, not to the exploding shell of the white dwarf in the nova binary system, but to the red companion of the white dwarf star. According to this theory, the red star in A0620-00 is somewhat larger than in an ordinary nova binary system and the two stars are closer together than is usual. It is further hypothesized that the red star may eject gas abruptly and in large amounts instead of in the steady stream of an ordinary nova binary. After circulating around and then falling on the white dwarf, the gas would supposedly produce X-rays. They, in turn, would radiate back to the red star and heat its surface, making it shine more brightly and thus producing the visible outburst of light.

A third, less complex concept has been proposed by several groups and is probably the most popular explanation at the moment. This theory suggests that A0620-00 is a nova binary system in which the small star is not a white dwarf but an even more compact object with a far stronger gravitational force at its surface—either a neutron star or a black hole. In this case, the additional energy generated by matter from the red star falling in the more powerful gravitational field of the compact object might suffice to produce the X-rays.

In ancient times, novae were regarded as omens. Today we take a more conservative approach to the influence of the stars on humans, but surely the discovery of the two novae of August 1975 bodes well for progress in scientific understanding.

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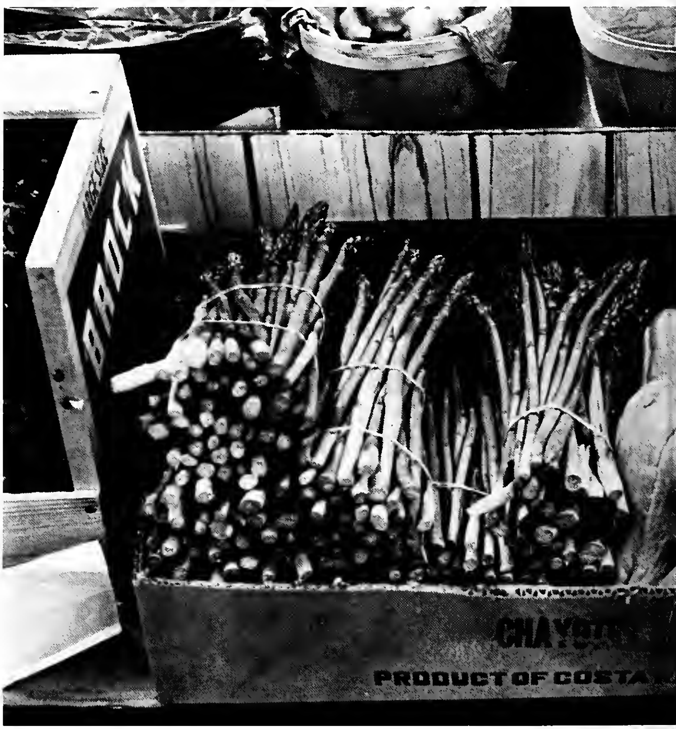
An Early Riser

Asparagus is one of the first and tastiest crops of the season

Long ago, when I was a boy, I hated asparagus. It was the only food (except for cooked carrots) that I didn't like. This dioecious perennial native of the Mediterranean littoral seems to be an acquired taste, at least in my family, for my children also pushed it aside on first acquaintance. I hope they will continue to follow in my footsteps and learn to love the tender shoots of *Asparagus officinalis.* My own conversion was dramatic, perhaps unnecessarily so: lunch outdoors in the Piazza San Marco, Venice, with a strolling band across the square, an August sun, and a plate of giant white asparagus (etiolated from being kept buried by the canny growers) in a fine vinaigrette.

I was nineteen and had no way of knowing then that I had joined an age-old tradition. The ancient Romans cultivated asparagus. Even before them, the Greeks had known enough



Angel Soccodato

by Raymond Sokolov

to eat the tender shoots that later turned to fern and fruited with berries. Indeed, the word *asparagus* comes to us directly from Greek. Homer used the word (actually *asparagos*) to mean windpipe. Should we conclude that later-born Hellenes borrowed the term for a pharynx-shaped vegetable? Perhaps. But more important, we do know that the plant mentioned by Greek authors of the classic period is virtually the same as the wild asparagus that grows today on the Mediterranean coast. Asparagus has not been changed by the pas-

sage of time or by wide variations of climate and soil.

If you served Samuel Pepys a plateful, he would not notice a difference between your bunch and the bundle of "sparrowgrass" he bought for one shilling and sixpence in Fenchurch Street, London, in 1667. Today, we take for granted early asparagus and frozen asparagus all year round. But in the seventeenth century, Louis XIV beamed with pride when a French hothouse forced asparagus for his table in January.

Asparagus came to the United States in colonial days. And American growers were not slow to adopt advanced methods. President Blair of William and Mary College wrote in his diary that he got asparagus from a hothouse in March of 1773. This was obviously a luxury crop. And even ordinary seasonal asparagus remained so in most places until the nineteenth century. The French started a research center at Argenteuil about 1860 that produced a now-standard commercial variety and made Argenteuil forever famous for its asparagus. At about the same time, canned white asparagus from California appeared on the market here. Nowadays, we measure the total domestic output in thousands of hundredweights. In 1973, this country produced 254 million pounds of asparagus, about one-third of it for the fresh market and the rest for processing. This, however, represents a sharp decline from the all-time record asparagus year of 1959 when 363 million pounds were grown.

Not only has our crop declined by 30 percent but the yield per acre has also fallen, from a high of 2,900 pounds in 1946 to 2,200 pounds in 1973. These downward trends are, apparently, real trends and not momentary seasonal variations. Worse still, for the asparagus lover, is that it is not a simple matter to reverse the slump. Asparagus takes, conventionally, three to four years to produce mature, harvestable shoots. A farmer has to believe asparagus has a commercial future before he will tie up land and fertilizer (asparagus is a voracious feeder) for that long, while the matted root system, or "crown," takes hold. Once established, asparagus will produce for decades. It is the most permanent of all vegetable crops.

The home gardener who has plenty of bed space and who doesn't mind taking the long view, can insure a

supply of fresh, tender shoots by buying three-year-old crowns and planting them in rich, well-drained soil in rows five feet apart and a foot deep (with each crown at least a foot from its nearest row-neighbor). Then wait a year.

The classic American variety is known, patriotically, as the Martha Washington. By now it is too late to plant even for next year's harvest, but others have been at work for your benefit. The over-all asparagus slump notwithstanding, 85 million pounds is a lot of fresh asparagus. The season continues until the beginning of summer in late June.

Seize the day. And take a minute or two extra so that you don't ruin this treat. Asparagus can be wonderful, but too often they are either overcooked into limp nullity or too hastily cooked, leaving them fibrous and half-edible.

Peeling is the key to success. Take a small knife and cut into the base of the spear. Go in far enough so that you leave tender flesh. Cut away less and less as you get closer to the tip. Also cut away the scales on the stalk (they are really leaflike bracts).

Wash the peeled asparagus, line them up, and tie them into bundles about as thick as your forearm at the elbow. Even off the bundle by cutting from the bases of longer stalks.

Bring a generous amount of salted water to a full, rolling boil, about 6 cups per bundle. Use a pot large enough to let you lay the bundles down horizontally in the water, which should cover the asparagus amply. You want this much water so that the cold asparagus will lower the water temperature as little as possible. Bring the water back to a full boil, then reduce heat and simmer, uncovered, for 12 to 15 minutes. Asparagus is done when a knife goes easily into the thickest end (if there is extreme variation in stalk diameter, try to group the thin and thick stalks in separate bundles so you can remove each bundle as it becomes ready). Remove the bundles carefully. Untie them after they have drained.

Asparagus can, of course, be served hot or cold. It is probably tastier hot, straight from the cooking water. Ambitious cooks will take this opportunity to show off their skill at hollandaise sauce or its cousin maltaise (substitute orange for lemon juice, preferably the juice of blood oranges—for their red color—in any

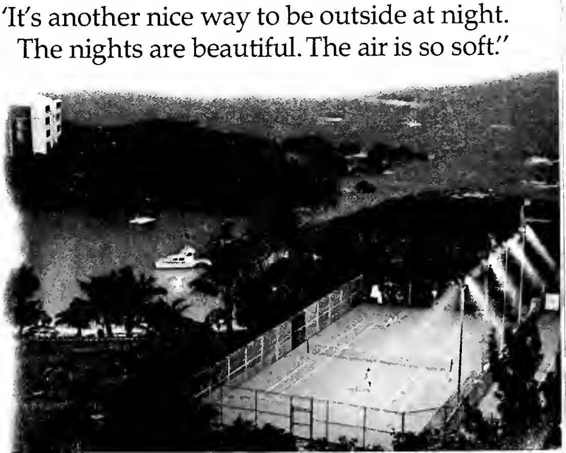
standard recipe). Cold asparagus goes magnificently with vinaigrette or mayonnaise.

But there is no need to stop there. When the season is on and the price drops within reason, you can use asparagus spears as a garnish for chicken or an omelet filling. Or cover hot asparagus with Mornay sauce, sprinkle with Parmesan cheese, butter, and breadcrumbs, and glaze under the broiler. *Asperges à la flamande* is hot asparagus served with hot, halved hard-boiled eggs on the side; guests mash the egg yolks in melted butter and make their own sauce at the table. A similar idea is *asperges à la Fontenelle.* Serve hot asparagus with melted butter and soft-boiled eggs. Guests dip the asparagus in the butter, then in the egg.

A very elegant and unexpected French procedure treats asparagus more or less as we usually treat potatoes when we mash them. Cook the asparagus as usual, in boiling, salted water; then purée in a blender or food mill. Push through a fine strainer. Heat with plenty of butter and some heavy cream. Season to taste and serve as a side dish with almost anything.

Once you have gone this far, there is no reason not to try a soufflé, which is, in this case, merely an asparagus purée, lightened with egg and baked (see recipe below). Almost all vegetable soufflés can be constructed on this model. You cook the vegetable, purée it and add cream if it is too watery (the asparagus purée needs no cream and will give you a standard of viscosity to follow with other vegetables). Then, for every half pound of purée, use three egg yolks and three whites. (Season heavily after you add the yolks to the purée because the addition of the beaten whites dilutes the taste.) Sometimes you may want to add an extra white to this formula if the batter looks especially heavy.

Or, for the ultimate in speed and freshness of taste, overcome your fear of frying and cook breaded asparagus tips in hot oil. This can be done quite simply in a skillet. Roll the asparagus tips (which should be only four or five inches long) in beaten egg yolk, then in bread crumbs. Plunge in very hot oil, which will "surprise" the fresh taste of the vegetable and lock it in. Fry only two or three tips at a time so that the oil's temperature does not fall too greatly when you first put in the asparagus. Turn the spears when a crust forms on the bot-



tom. Wait for a crust to form on the other side, drain, and hold in a warm oven until the whole batch is done. This can all be done very quickly with a miniproduction line of yolk and crumbs. You might even want to use two skillets for extra speed. The result, after a little fuss and muss, is a brilliant conjunction of man and vegetable.

Asparagus Soufflé

1¼ pounds fresh (or 1 pound frozen) asparagus
Butter
Grated Parmesan cheese
6 egg yolks
Salt
Pepper
7 egg whites

1. Preheat oven to 325 degrees.
2. For fresh asparagus, cook according to the boiling method described. For frozen asparagus, follow the directions on the package and drain.
3. Purée the asparagus in a blender or a food mill, then push it through a fine strainer and let it cool in a bowl. You should have about 1½ cups.
4. Meanwhile, butter the inside of a 2-quart soufflé dish or charlotte mold. Dust the buttered surfaces with Parmesan cheese and set aside.
5. Beat the egg yolks into the cooled asparagus purée. When well blended, season with salt and pepper to taste.
6. Beat the egg whites until stiff but not dry. Stir a small amount into the asparagus mixture, to lighten it. Then fold in the rest of the egg whites.
7. Pour the soufflé mixture into the prepared mold. Gently smooth off the top. Bake immediately at the lowest level of the oven for approximately 40 minutes. The soufflé is done when it has browned on top, risen fully, and started to pull away from the sides of the dish.
8. Serve immediately.

This soufflé will not have a runny center. The batter is too heavy to cook well at the higher heat required to produce that effect.

Yield: Six servings

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*

The Hunter Hunted

THE HUNTING HYPOTHESIS, by Robert Ardrey. *Atheneum Publishers, $10.00; 231 pp.*

Robert Ardrey's latest book is dedicated to Raymond Dart. Professor Dart's study of the bones from the Makapansgat cave in South Africa led him to believe that *Australopithecus africanus*, an early hominid that might have been ancestral to later humans, was responsible for the bone accumulations. Dart believed that these little hominids not only gathered bones in the cave but that these were from wild animals that they had hunted and butchered on the veld. Dart saw his evidence as proof that this predatory habit, including the killing of other *Australopithecus* individuals, was such a basic adaptation that it became central to later human development. For a variety of reasons Dart's ideas were not accepted, at least not in unabridged form, by most anthropologists. Ardrey is convinced of the fundamental importance of Dart's work and has taken it upon himself to become the Huxley for Dart's Darwin. The thread that ties his work together, from *African Genesis* to *The Hunting Hypothesis,* is his conviction that a predatory way of life is indeed *the* basic hominid adaptation. He has formulated his hypothesis in this way: "While we are members of the intelligent primate family, we are uniquely human even in the noblest sense, because for untold millions of years we alone killed for a living."

Critics have attacked Ardrey on several grounds, one of the most important being that he is too enamored of the "nature" side of the nature–nurture argument concerning the control of animal behavior. Instead of adding more general criticism, I will examine some of the issues so that the reader—who might be carried along on the swell of Ardrey's prose—can see for himself that there might be reasonable, alternative interpretations of the data.

Taking some of the points in time order, I will start with *Ramapithecus*. This is a little-known fossil primate from Africa and Eurasia found in deposits ranging from about 13 to 10 million years old. It may well be the earliest recognizable member of our own family, the Hominidae, and as such is immensely important for students of human origins. The fossils from Kenya come from one of the late Louis Leakey's sites near Lake Victoria, where there are thousands of other bones of many animals concentrated in a small area. Ardrey states that the fossils were buried by a volcanic ash fall, but my studies show they were concentrated in small channels in soils. Ardrey questions whether smashed bones and one dubious stone tool are strong enough evidence to show that 13 million years ago *Ramapithecus* had embarked on the hunting and tool-using way of life.

However, Ardrey makes it clear what he would prefer to believe, since he later talks of this same living site of *Ramapithecus* as differing not at all from that of much later hominids at Olduvai. To say that two assemblages of bones and stones do not differ at all is incautious. I have had the privilege of excavating further at this *Ramapithecus* site. There is no evidence to suggest that the bones were concentrated by other than natural agencies or that they were broken by other than nonhuman carnivores, depositional processes, and weathering. The one lump of stone that Leakey suggested was a tool has no artificial breaks and is not evidence of stone use.

Ardrey speculates that the lack of a defensive canine in *Ramapithecus* probably is correlated with the use of defensive weapons, despite the lack

of evidence of weapons. This idea is based on his belief that we are the only primates with reduced canines. While this might be true of living primates, there have been other lineages in the past, including some extinct apes and lemurs, with the same adaptation. Further, I would contend that the behaviors and body parts used by animals for defense developed primarily for use in intraspecific interactions. Thus the long canines of male baboons, like the horns of antelopes, evolved in response to baboon (or antelope) behavior. That these behaviors or body parts might also be used in defense is a secondary benefit. It is unlikely that they evolved as antipredator mechanisms and were secondarily used against conspecifics. If long canines have not evolved primarily for defense against predators, then short canines do not imply the necessity for another sort of weapon.

Ardrey's discussion of *Ramapithecus* is set against a background of another favorite concept—the Pliocene drought. He uses two main lines of evidence to support the contention that drought conditions lasted for a long period in Africa. The first is from studies of Mediterranean sediments, which show that for part of the Pliocene the Mediterranean Sea evaporated. Although drought may cause the evaporation of large bodies of water, in this instance there is ample evidence that the Mediterranean dried up because it was cut off from its main water input, the Atlantic. This whole process was a direct consequence of the movement of the African continental plate northward toward the Eurasian one.

The second line of evidence is the scarcity of Pliocene fossil deposits. Ardrey postulates that there was not enough rain to turn bones into fossils. This is clearly a great misunderstanding of the basics of African geology. Since long before the Pliocene there has been very little continental sedimentation in most of Africa, not because of a lack of rainfall, but because of the stability of the geomorphology of the continent. If a dearth of fossil beds indicates lack of rainfall, then Africa has been a desert over most of its area for the last 70 million years. But known Pliocene fossil sites show an adequate fauna with no representation of desert animals. Similarly, the earlier Oligocene period is known from only one African fossil site, but that does not mean that the rest of Africa was desert.

More reliable evidence of dry conditions in Africa is the existence of extensive sand beds, but it is now thought that these sands are much older than the Pliocene. Other sources, such as the coastal record, do indicate climatic fluctuations, but there is no evidence of an over-all trend toward increasing aridity during the Pliocene. According to Ardrey, this drought, for which there is little or no evidence, decreased the areas of forest and thus forced early hominids into more open country. Because of the need to exploit new and unfamiliar food resources, these early hominids took up hunting, bipedalism, tools, and weapons.

Many of his arguments are used by proponents of the single-species hypothesis of human origins, who argue that if canine reduction is a consequence of tool use, then culture itself is the original and basic hominid niche. Since no two closely related species can be expected to exploit the same niche in the same place at the same time, it is therefore unlikely that any two species of hominid ever existed at the same time. New evidence from Kenya now appears to have invalidated the single-species hypothesis, and thereby its basic arguments, without much question. Richard Leakey has just discovered a nearly complete cranium of a *Homo erectus* that is clearly contemporaneous with a large robust *Australopithecus*. These two hominids are so different morphologically that even the most ardent single-species advocate has never lumped them into a single species. It may be difficult to believe that two hominid species could live in the same area at the same time and yet the evidence shows that they did. The important point is that both these creatures had features that Ardrey associates with hunting. I believe it will take more critical examination of the evidence and less speculation if we are to understand exactly what the basic hominid adaptation is and why the hominid morphological complex developed.

Ardrey briefly recapitulates Dart's evidence from South Africa concerning the hunting abilities of *Australopithecus africanus*. This is the crucial evidence to Ardrey, for he believes it demonstrates the antiquity of human predatory habits, and it was the evidence that stimulated his interest in human origins. I do not believe that the evidence from Makapansgat shows that *Australopithecus* hunted

animals, carried bones into the cave, or scavenged from carcasses outside the cave. In the past few years we have seen the development of a branch of paleontology known as taphonomy—the science of burial and fossilization—which examines various factors that affect the representation of any original plant or animal community in the fossil record. A recent study has pointed out that there is no easy way to identify the predator or scavenger of any one bone assemblage by examining the representation of various parts of different prey species, and further, that breakage patterns of bones will not necessarily identify the breaking agent, whether this is animal or not. Thus the sort of evidence used by Dart—patterns of bone breakage, disproportions of various parts of different types of skeletons, or even disproportions of different parts of the same bones—cannot be used to show whether or not *Australopithecus*, carnivore scavengers, or natural weathering and concentrating processes were responsible for the type of bone accumulation found at Makapansgat. In short, there is no evidence to indicate whether *Australopithecus* was or was not a hunter or scavenger.

The earliest record of hominids collecting bones and breaking stones, for whatever reasons, comes from East Rudolf in Kenya. (Mary Leakey, although she has found early hominid remains dating back to about 4 million years ago, found no evidence of stone breaking with them—and if anyone could find it, she could!) As things stand at present, the earliest certain appearance of hominid-broken stones was just over 2 million years ago. Mary Leakey has found evidence that early hominids at Olduvai were butchering the remains of two very large animals at about this same time. Ardrey calls these definite slaughtering sites, but in her original report, Leakey is careful to point out that one animal probably died of natural causes and that the hominids either came upon the other accidentally or drove it into a swamp. This shows that hominids butchered dead animals, but it does not allow us to say whether this followed a hunt or not; no amount of speculation will help us further. I do not dispute that there is evidence of hominid hunting activities after about a million and a half years ago. Since there is not much that will destroy a stone tool, the record of early hominid behavior will

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be biased in favor of activities involving tools. Any of a broad range of other possible behaviors will leave few or no traces, but if hunting involved the use of stone tools, then the record of hunting will be overrepresented.

Ardrey also speculates on many aspects of the Acheulean stone tool culture and *Homo erectus*. His most revealing comment concerns the famous hand axes, which he says were beautiful far beyond their functional demand. But what were these hand axes used for? We simply do not know their function and it is specious to comment on their beauty relative to function.

Whenever the evidence is to be interpreted, Ardrey will espouse the most violent, catastrophic, and dramatic choice—endless droughts, burial by volcanic ash, slaughter, cannibalism, head hunting, and the like—as though there were no steady, slow, undramatic processes in the world. As one last example I will mention the *Homo habilis* individual from Olduvai that Ardrey says apparently died of a blow to the top of his head. We shall never know what he or she died of, but we do know that the two gently curved bones of the top of the skull were covered by a layer of sediment that consolidated under the immense pressure of the overlying rock. It is surely more reasonable to think that the blunt object that produced the radial cracks on the bones was the sediment itself, rather than that a murder was committed 2 million years ago, if only for the reason that we know that the sediment did press.

I do not think that Ardrey has much incontrovertible evidence to support his hypothesis that all our unique human attributes have evolved because we were hunters for untold millions of years. His anecdotal style and his flair for personalizing evolutionary events make it difficult to know whether he really knows all the ifs, buts, and maybes of each successive controversy. It will be especially hard for the intelligent general reader to know the violence that the blunt object of Ardrey's conviction has dealt to the evidence.

Alan Walker is an associate professor of anatomy and anthropology at Harvard University and has worked for many years on problems of primate and human evolution in Uganda and Kenya.

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Additional Reading

Hummingbirds (p. 24)

Arthur C. Bent's *Life Histories of North American Cuckoos, Goatsuckers, Hummingbirds and Their Allies,* originally published in 1940 as part of a monumental 23-volume series on the natural history of our avifauna, is now available as an inexpensive reprint (New York: Dover Publications, 2 vols., $3.00 each). In contrast to Bent's species-by-species summaries, Alexander F. Skutch presents a colorfully illustrated monograph on hummingbirds as a group in his *Life of the Hummingbird* (New York: Crown Publishers, 1973). Crawford H. Greenewalt's *Hummingbirds* (Garden City: Doubleday, 1960) has become an expensive collector's item for both the ornithologist and bibliophile, but many libraries have copies. Some of the book's superb illustrations, plus an account of the technical problems overcome by Greenewalt in these original studies, are in his *National Geographic* article "The Hummingbirds" (1960, vol. 118, pp. 658–80).

Geographical, ecological, and behavioral aspects of the coevolution of plant and animal in hummingbird flower pollination–hummingbird feeding relationships are explored in Karen and Verne Grant's *Hummingbirds and Their Flowers* (New York: Columbia University, 1968). Another case of coadaptation is described in Donna Howell's "Plant-loving Bats, Bat-loving Plants" in the February 1976 issue of *Natural History.* Technical accounts of hummingbird energetics may be found in William C. Calder's "Consequences of Body Size for Avian Energetics" in *Avian Energetics,* edited by R. A. Paynter, Jr., (Cambridge: Nuttall Ornithological Club, 1974, pp. 86–144), and in two *Science* articles: "Energetics of Foraging Rate and Efficiency of Nectar Extraction by Hummingbirds" (L. A. Wolf et al., 1972, vol. 176, pp. 1351–52) and "Regulation of Oxygen Consumption and Body Temperature During Torpor in a Hummingbird, *Eulampis jugularis*" (F. R. Hainsworth et al., 1970, vol. 168, pp. 368–69).

Earthquake (p. 30)

Oskar H. Spate and A. T. Learmonth's geography *India and Pakistan: Land, People, and Economy* (New York: Barnes & Noble, 1972, $8.75) provides

extensive background information on the region of Pakistan devastated by an earthquake in 1974. Fredrik Barth's "Ecological Relationships of Ethnic Groups in Swat, North Pakistan" in *Environment and Cultural Behavior: Ecological Studies in Cultural Anthropology*, edited by Andrew P. Vayda (New York: Doubleday/Natural History Press, 1969), deals with aspects of human ecology and coexistence of different groups of people in that earthquake-prone area. Erik P. Eckholm's recent pieces for *Natural History* ("The Firewood Crisis," October 1975) and *Science* ("The Deterioration of Mountain Environments," 1975, vol. 189, pp. 764–70) review different facets of the detrimental impact of man's activities in tropical and subtropical mountain regions of the world. Report #14 in UNESCO's Man and Biosphere Program, entitled "Impact of Human Activities on Mountain and Tundra Ecosystems," is available free of charge from UNESCO Documents Division, 7 Place de Fontenoy, 75700 Paris, France.

Gems (p. 38)
The full-color illustrations in *Color Under Ground: The Mineral Picture Book*, by Lee Boltin and John S. White, Jr., (New York: Charles Scribner's Sons, 1971, $6.95), demonstrate the incredible variety of form and color found in the world beneath our feet. Diagrams, photographs, and a concise text introduce the classification of crystals by symmetry, the replacement of living forms by minerals, and the plantlike shapes often adopted by crystal groups in their growth. Brian Mason and L. G. Berry's *Elements of Mineralogy* (San Francisco: W. H. Freeman, 1968) is a nontechnical, yet comprehensive, introductory textbook for the study of minerals. Richard M. Pearl's *Rocks and Minerals* (New York: Barnes & Noble, 1969, $2.75) is a broad, lucid survey of mineralogy, crystallography, gemmology, and economic geology. *Minerals and Man*, by Cornelius S. Hurlburt, Jr., (New York: Random House, 1968), presents the nature and origin of the world's important mineral deposits, along with accounts of their past and present use. Hurlburt has also recently prepared the 18th edition of *Dana's Manual of Mineralogy* (New York: John Wiley & Sons, 1971), an easily read introduction to the science, and an extensively used college text and reference work.

Urban Herpetology (p. 46)
Donald Loggins has prepared a "Bibliography on the Natural History of an Urban Area: New York," which is available for $1.50 from the Council of Planning Librarians, P. O. Box 229, Monticello, IL 61856. Although somewhat weak in modern ecological theory, *Nature in the Urban Landscape: A Study of City Ecosystems* (Baltimore: York Press, 1973), by Don Gill and Penelope Bonnett, is one of the best sourcebooks on urban ecology. C. J. Krebs's *Ecology: The Experimental Analysis of Distribution and Abundance* (New York: Harper & Row, 1972) presents general ecological theory. A good aid for the identification of amphibians and reptiles is Roger Conant's *A Field Guide to Reptiles and Amphibians of Eastern and Central North America* (2nd ed. Boston: Houghton Mifflin, 1975).

Brain Evolution (p. 54)
W. I. Welker and G. B. Campos's "Physiological Significance of Sulci in Somatic Sensory Cerebral Cortex in Mammals of the Family Procyonidae" (*Journal of Comparative Neurology*, 1963, vol. 120, pp. 19–36) is the article that first stimulated Leonard Radinsky's interest in comparing the cerebral cortices of extinct and living animals for evidence of brain evolution. Harry J. Jerison's *Evolution of the Brain and Intelligence* (New York: Academic Press, 1973) is a compendium, dealing mainly with relative brain sizes of various groups of vertebrates, which gives one approach to the investigation of brain structure and overall functioning of animals. "The Casts of Fossil Hominid Brains," by R. Holloway (*Scientific American*, 1974, vol. 231, no. 1, pp. 106–15), indicates the limits of interpretation possible with endocasts of our own prehistoric ancestors. In "Primate Brain Evolution" (*American Scientist*, 1975, vol. 63, pp. 656–63), Radinsky deals with major trends in the evolutionary development of primate brains and discusses how endocasts of fossil primate braincases can suggest when these specializations occurred.

Gordon Beckhorn

Announcements

The American Museum of Natural History opens its new **Hall of Minerals and Gems** (southwest corner of the first floor) on Friday, May 21, 1976. This will be a spectacular and elegant exhibit with an impressive array of minerals, gems, rocks, and meteorites. For a limited time, the Hall will also house a special exhibit of nine world-famous, American-owned diamonds, including the Tiffany Diamond, valued at $5 million; the Eugenie Blue, a heart-shaped diamond reported to have belonged to the Empress Eugenie; and the Zale Light of Peace (130.27 carats), the largest modern-cut, pear-shaped diamond. The Hall, the largest in the Museum, will treat such major subjects as properties of minerals, mineral-forming environments, systematic mineralogy, interaction of minerals and energy, and esthetics of gems.

The huge, curvilinear Hall is a bold departure from traditional boxlike exhibition areas. Its multiple levels—with ramps and steps leading to individual displays—are expected to generate a heightened sense of involvement on the part of visitors. The earth-toned floor and wall carpeting provide a color scheme that suggests earth and its treasures. Two major objectives influenced the Hall's design: (1) to display the richness, variety, and dramatic beauty of earth materials; and (2) to explain their properties, the profound subterranean forces that produced them, and their significance to human societies throughout history.

On Saturday, May 8, from 12 noon to 4:45 P.M., the Museum will celebrate **Earth Day**. Participants will include energy groups, neighborhood improvement groups, and environmental education programs. The following special events are scheduled. In the People Center, Dr. Helen Ross Russell will discuss "Foraging for Wild Edible Plants" and "Organic Foods," Mitchell Korn will perform "Earthtalk Music Compositions" for 12-string guitar, and David Seymour will give a slide presentation of the ecology of the Hudson River. In the Calder Lab, Karen Bennett will give a presentation on the art of making natural dyes from household products, and Wendy Levy of the Available Resource Center will demonstrate how to create educational materials and games out of industrial waste products. And in the Hall of Mexico and Central America, Joyce Timpanelli and Charles Simons will tell and illustrate earth stories and myths. From 1:00 to 4:00 P.M. the following documentary films will be screened in the Auditorium: *The End of the Game*, an examination of Africa's vanishing wildlife, and *Menagerie*, on the conditions of the animals in Central Park Zoo.

Eco-Visions, a film series presented by the Environmental Information Center of the Museum, can be seen from 1:30 to 3:00 P.M. on Thursdays in the Education Hall, and at 2:00 and 3:00 P.M. on Saturdays in the People Center. For details on films to be shown call 873-1300, Ext. 527 from 10:30 A.M. to 12 noon, Tuesday through Friday.

Reservations are still being accepted for the Museum's **East African Geological Safari** in August. Visits will be made to the major game parks and reserves in Kenya and Tanzania, in addition to mines, volcanoes, the famed Rift Valley, and other sites of geologic significance off the beaten track. A day will be spent in the company of Dr. Mary Leakey at Olduvai Gorge. The trip has been arranged and will be conducted by Christopher J. Schuberth, lecturer in geology at the Museum and adjunct professor of geology at the City University of New York. For a descriptive brochure, write or call (873-7507) the Museum's Department of Education.

Trout Flies continues through May in the Roosevelt Memorial Hall, second floor of the Museum. This extraordinary collection combines historic and contemporary examples of the flytiers art with paintings, photographs, etchings, and three-dimensional trout. The Museum Showcase features a framed collection of flies by Frederic M. Halford, the historian of the dry fly; flies by Theodore Gordon, the father of American fly tying; contemporary flies depicting nymphs and wet flies by Ted Niemeyer; studies of the materials used by flytiers; and a videotape of fly tying.

At the **Hayden Planetarium** of the Museum, "Things That Go Beep in the Night" continues through May. The invention of radio astronomy in the 1930s opened a new window to the universe enabling astronomers to "listen in" on distant galaxies, exploding stars, pulsating stars, quasars, and black holes. Sky Shows begin at 2:00 and 3:30 P.M. on weekdays, with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children.

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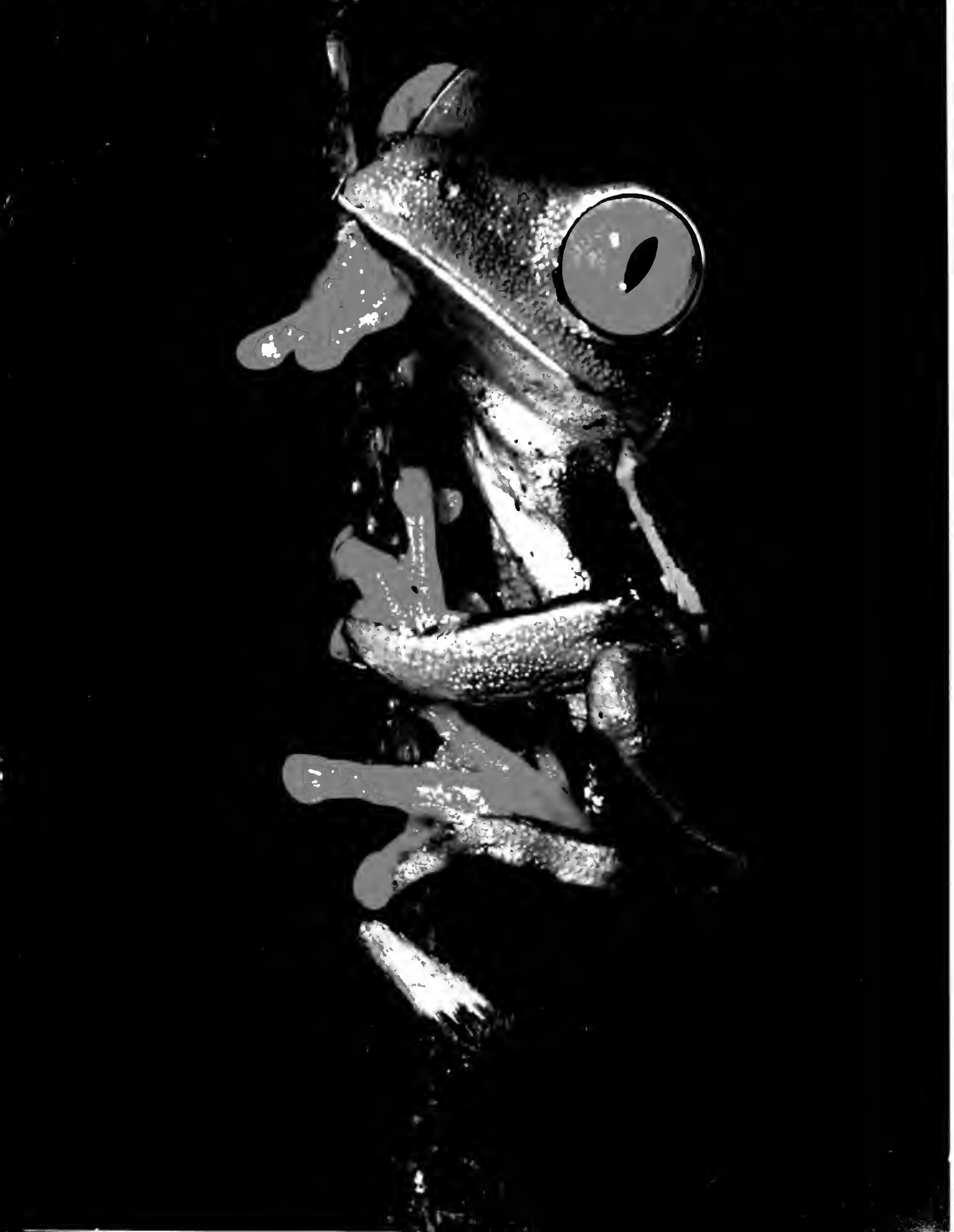

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Six years ago several Michigan environmental groups asked **Joseph L. Sax,** who teaches environmental law at the University of Michigan, to draw up legislation that would permit private citizens to take their complaints of pesticide misuse to court. Sax responded by designing a bill that evolved into the Michigan Environmental Protection Act (MEPA). After MEPA's passage, he monitored every lawsuit brought under the bill, a process that convinced him of the potential strength of legislation grounded in citizen participation. Sax is currently engaged in investigating policy issues associated with public land use, an interest that developed from his high regard for this country's national parks.

Margaret Mead first visited the Admiralty Islands in the southwest Pacific in 1928. She has returned six times, most recently last summer, to study changes occurring there as the Manus people have become part of the mid-twentieth-century world. In addition to interpreting a variety of preindustrial South Pacific cultures, Mead has studied aspects of contemporary society in the United States. Her extensive research has resulted in an enormous volume of published material, including 24 books she wrote alone, another 18 books she coauthored or edited, and numerous scientific papers, monographs, and popular articles. Now curator emeritus of ethnology at The American Museum of Natural History, Mead has been associated with the Museum since 1926. In addition, she is immediate past president and current chairman of the board of the American Association for the Advancement of Science.

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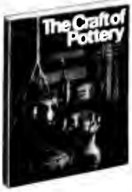

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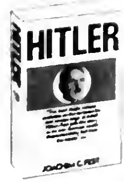

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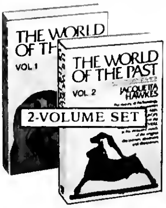

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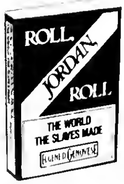

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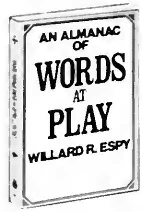

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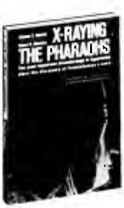

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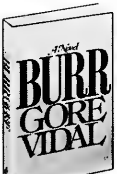

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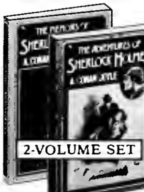

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While honeymooning on Saint John, U.S. Virgin Islands, **Bruce E. Coblentz** noted the effects goats were having on the native vegetation. He became more interested in these ruminants when he learned that there was an almost complete lack of scientific information on feral goats, despite their being a dominant ecological force. An assistant professor of wildlife ecology at Oregon State University, Coblentz began his study of feral goats and their impact on plant life on Santa Catalina Island, California, in 1971. He is continuing with this work and has plans to research the distribution, density, and productivity of wild pigs on the island.

Temporarily abandoning her scientific objectivity, **Patricia W. Spencer** admits to "loving" the annual return of colorful fruits and flowers to her garden. Her research into plant coloration grew out of her enthusiasm and curiosity over the ability of a handful of pigments to produce such a variety of colors in the plant world. A plant physiologist in the Department of Horticulture at the University of Illinois. She is researching biochemical aspects of apple tree nutrition, with particular emphasis on nitrogen transport mechanisms. In addition, Spencer and her husband, an electrical engineer, have formed a corporation to develop clinical and research instruments employing fluorescence techniques.

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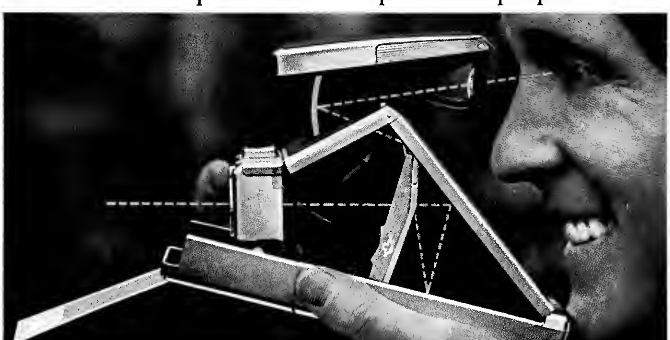

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National 4-H Forestry Award winners, front to rear: Jeffrey Little, John Pfleiderer, Melinda Hadden, Craig Jerabek, Steve Welches, and David Doherty, Jr.

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Together, Craig Jerabek, David Doherty, and Jeffrey Little planted over 57,000 of the 60,000 seedlings — enough to keep a city of 16,000 people supplied in paper for an entire year when the trees are grown.

Melinda Hadden's specialty is *Christmas* trees — she's planted 1,200 of them. She's also planted about 300 trees for homeowners whose trees were destroyed by a violent windstorm.

John Pfleiderer has researched and fought Dutch elm disease — a killer which wiped out many of Greeley, Colorado's most beautiful trees. (John also taught himself grafting — and created new forms of trees.)

But there's more to a forest than just trees. Healthy forests are a complete ecosystem. That's why Steve Welches has planted over 1,200 shrubs for animal cover. And why David Doherty has built dens and brush piles for rabbits and small game birds. (And succeeded in bringing them back to land that was once ravaged by Hurricane Camille.)

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Environmental Action: A Passing Fad?

by Joseph L. Sax

Michigan enacted a model law to defend the environment . . . but that was before the energy crisis and the recession

Six years ago, at the height of public enthusiasm for environmental protection, the State of Michigan undertook an experiment in public participation that some of the area's industrial and political factions greeted with alarm. The cause of their concern was the enactment on July 27, 1970, of the Michigan Environmental Protection Act (MEPA). Stated simply, the statute declared that "pollution, impairment, or destruction" of the state's resources was illegal.

MEPA was unusual in several respects. Not only did its passage imply a right to environmental quality, it also took the traditional monopoly of law enforcement out of the hands of public officials. The new law empowered any citizen to institute a lawsuit claiming violation of the statute; further, such suit could be brought against any private or public entity—a utility company, the highway department, a shopping center developer, the governor, or even the state itself.

If the plaintiffs could prove their case in court—that environmental impairment or destruction had occurred or was likely to occur—they were entitled to a court order prohibiting the defendant from continuing the detrimental actions. MEPA was unabashedly designed to cut environmental despoilers down to size.

From the retrospective view of six years, it is plain that neither the worst fears of MEPA's critics nor the rosiest expectations of its proponents have been realized. The law's operation has, however, provided some rare insights into the complexities of citizen participation statutes.

One of the fundamentals of MEPA was that it provided not a single penny from the public treasury to finance litigation. Nor, as it happened, did Michigan become a recipient of the largess of big private foundations during the days when they were so generously financing public interest law firms. The lack of funding went hand in hand with the lack of young, idealistic lawyers who usually frequent such firms. They were attracted to Washington, San Francisco, and Denver, leaving Grand Rapids to shift for itself. As a result, no cadre of enthusiasts existed to institute test cases when the new statute became effective.

More surprisingly, the established environmental organizations in the state did not have an agenda of planned environmental litigation. A few weeks after Gov. William G. Milliken signed the law, all the organizations that had worked for MEPA's enactment met and agreed that for the good of the environmental movement, and to safeguard its legislative victory, care should be given to the selection of the first test cases to be brought under the statute. The floor was opened for discussion of each group's plans for the litigation it sought to initiate. Not a single group had even the germ of a plan.

Local property owners' associations brought fully half the early suits, which focused on pollution caused by burgeoning second home and condominium developments around Michigan's lakes. Several other suits were begun by local residents to force a town to modernize or enlarge its sewage treatment plant. One or two cases were nothing more than traditional nuisance-type suits dressed in new environmental clothing: a rural resident, for example, sued a neighboring pig farmer for failing to keep odors down to a tolerable level.

Although somewhat inconsequential, these early cases proved that the courts would receive MEPA cases seriously and that they would not throw up technical and procedural roadblocks. This knowledge initiated a new kind of case, and the full possibilities of MEPA began to reveal themselves for the first time. By the summer of 1971, the MEPA docket began to harbor a series of issues that had rarely, if ever, been heard in Michigan courthouses.

In one action, Trout Unlimited, a sport-fishing organization, called on Governor Milliken to prevent the drainage of a lake into the Au Sable River, one of Michigan's most celebrated trout streams. The controversy

arose when a heavy winter snowfall raised the waters of cottage-lined Otsego Lake to record levels, threatening the homes with flooding. Approval had already been given to an ill-conceived plan to channel water from the lake into the Au Sable at a rate that threatened the river's quality. Trout Unlimited had come up with a technically sound and more moderate plan to relieve pressure on the lake, but it could not be heard for the din made by the cottage owners. Working under the pressure of an imminent court hearing on an injunction, however, the parties did some hard negotiating. A compromise plan was developed, accepted by all, and signed by the judge as a formal court order.

The Trout Unlimited case conveyed a message that was well understood: MEPA not only gave environmental groups a forum, it also gave them a power position, for if they could persuade a judge that there was merit in their case, they would be entitled to an enforceable court order. When the significance of this began to be widely understood, the statute took off. Groups that had for years had their pleas ignored by decision makers now had a means of making sure they were heard.

Soon, the law was invoked to stir public regulatory agencies out of their periodic episodes of somnolence. Michigan's Air Pollution Control Commission, like those of a number of other states, operated on the theory that it is better to negotiate patiently with polluters than to use the coercive means at its command. This attitude was a gift to recalcitrant industries. As one example, a Grand Rapids foundry had failed to comply with the Air Pollution Control Commission's regulations for four years. Traditionally, nothing could be done about such a situation if the commission did not undertake formal enforcement proceedings. Then a Grand Rapids environmental group took the Air Pollution Control Commission to court in a MEPA suit. The filing of the case resulted in the installation of the required pollution control equipment.

While the foundry case set no important legal precedent, it did create a precedent of another kind. For the first time, state regulatory agencies discovered that citizen groups dissatisfied with the way the law was handled could haul agency officials into court to explain their enforcement programs. The over-all result was that agencies began to reexamine their regulatory duties.

Cases challenging regulatory enforcement produced another interesting side effect. Because no outside funds subsidized MEPA cases, most citizen groups found their ability to use the law limited. However, the statute explicitly permitted the attorney general or any other public official (such as a county prosecutor) to begin a suit. Local groups found that these officials welcomed requests to bring suit themselves or to join with citizen groups.

Unpopular local pollution provided an attractive opportunity for elected law enforcement officials and a new and strongly worded statute gave them a solid legal basis for action. Also, local groups often made it clear that if an official did not act, the citizens might be forced to do his job for him, a potential embarrassment. A number of cases ensued in which the state attorney general and county prosecutors were plaintiffs.

Until 1973 all the cases had dealt with companies failing to comply with established pollution control regulations. But then the attorney general, Frank J. Kelly, took a new direction. He decided it was time to try a case that claimed the existing regulations had to be strengthened because they were not adequate to do the job.

The test case involved a blunder by the Air Pollution Control Commission. The commission had ordered a large enterprise, National Gypsum Company, to install new air pollution equipment. The order, however, was not sufficiently strong, and initiation of new proceedings leading to an amended order would have been complex and time consuming. The commission referred the case to the attorney general.

As the air pollution law stood prior to the passage of MEPA, nothing could be done because National Gypsum had not violated the order enforcing the law. But under MEPA the attorney general could, and did, go to court claiming that the commission's order was too weak and that the stipulations of MEPA required that it be strengthened. After some preliminary discussions, the commission, National Gypsum, and the attorney general renegotiated a substantially stronger compliance order, which set a stricter and shorter timetable for cleanup. The settlement was unanimously approved by the commission and was then made a binding court order.

The National Gypsum case stands for more than an upgrading of existing regulations. It shows the possibility of having a workable system in which regulatory decision making is subject to vigorous challenge and extensive judicial scrutiny. This is a dramatic and significant change in a governmental system such as ours, where enormous deference has traditionally been given to the judgments of experts (such as an air pollution commission).

Other cases moved beyond pollution to the frontiers of environmental law, for MEPA is phrased very broadly—covering not only air and water but the entirety of "natural resources and the public trust therein." Innovative cases included a suit asserting that lakefront land, acquired years previously by the highway department but never used, had in effect been dedicated to public recreational use and had thus become a part of the public trust. It could not, the plaintiffs claimed, simply be declared surplus land by the highway department and sold to a nearby motel for a parking lot. The court found the assertion of a public trust to be appropriate but said that, factually, there had not been sufficient public use over the years to support the claim of dedication to public recreational use.

During its first five years there was hardly a subject within the broad bounds of environmental law that did not generate a MEPA case: there were controversies over Indian fishing rights, deer hunting, land drainage, iron mining, a nuclear power plant, burial of contaminated cattle—even the construction of a county jail. Its very breadth predictably led to the challenge that MEPA was too broad to provide adequate standards to the courts. But in a unanimous opinion, the Michigan Supreme Court decisively rejected any such claim. By the time this mandate of support was issued in January 1975, MEPA had already become a major fixture in the state's system of environmental decision making.

Cases were not very numerous (about twenty-five per year), but in a few areas the law had indisputably made a mark. Regulatory agencies such as the Air Pollution Control Commission operated consciously in the shadow of a potential legal challenge as they negotiated with pollut-

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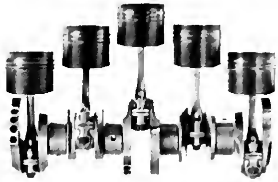

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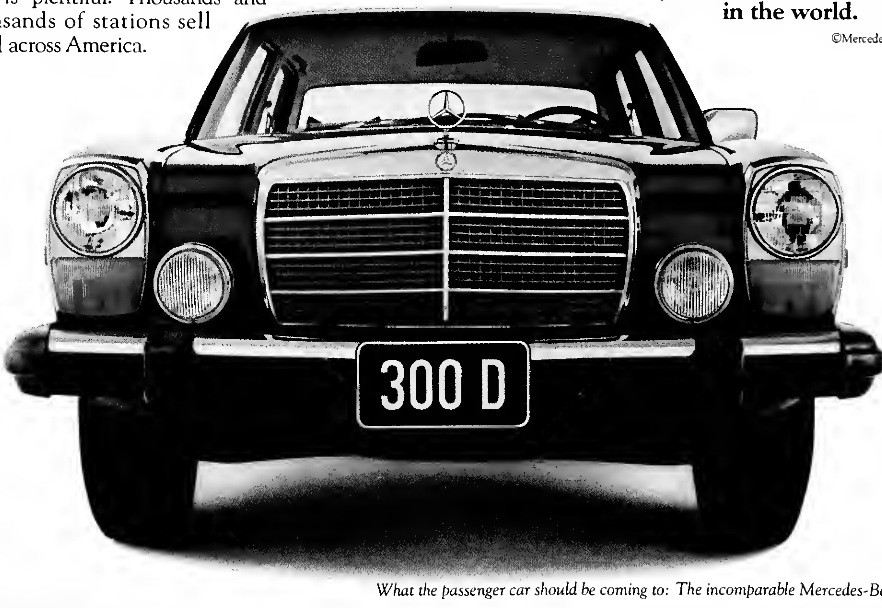

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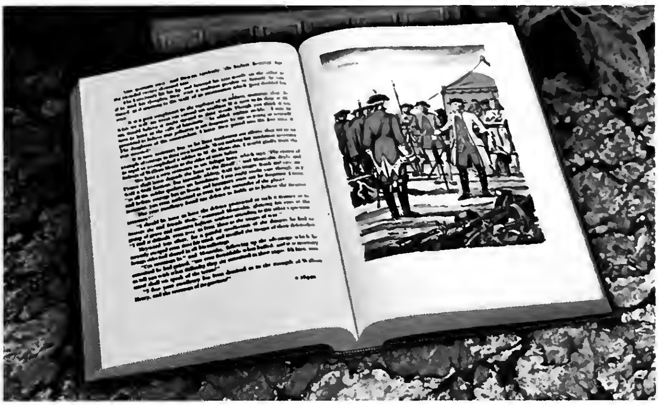

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ing industries. Recreational homesite developers—defendants in a number of vigorously fought MEPA cases—evidenced wariness in seeking to subdivide lakeshore property. Powerful bureaucracies, such as the county commission responsible for draining wetlands for agricultural development and the highway department, were the subject of critical supreme court decisions.

A case involving the State Department of Natural Resources represented the final recognition of citizen action as appropriate, rather than obstructive. The department was sued under MEPA for having granted a land developer a permit to dam a small, but prized, fishing stream. The case was not quietly settled, but went to a full judicial trial, with department officials—high and low—called to the witness stand to defend their action. Shock waves went through a bureaucracy that had never before had to explain how it justified its regulatory actions. The case was particularly troubling because it revealed the real reason for the granting of the permit. Department officials felt that without the permit the developer would nevertheless seriously damage the stream and they were reluctant to test their ability to prevent such an occurrence.

Although revelations of this sort were hardly calculated to endear the department to the public, its director, Ralph MacMullen, never succumbed to the temptation to blame MEPA for his own agency's limitations. Using the opportunity to rebuff MEPA critics, he praised MEPA as an example of environmental legislation that allowed private citizens an opportunity to dissent in court.

For all its successes, however, MEPA had never been used in any legal challenge to the state's major powers—the automobile, agricultural, or Upper Peninsula mining industries. This was not surprising for MEPA was a grass roots law that brought no money or big-time talent with it. It was designed for local citizen groups, for the small-town attorney, and for local courts.

The economics of litigation under the statute reveals the scale of its use. About 85 percent of the cases were disposed of without a trial. The cost of these cases averaged $2,000, but half of them were under $1,000. While settlement of controversies at a modest cost is admirable, budgetary limitations are a powerful constraint on many plaintiffs, and some cases were settled less favorably than was desirable because the money ran out.

Almost any environmental case requires aid from scientists or technicians, most of whom do not provide their services free of charge. In some of the cases, plaintiffs lacked the basic assistance required to put forward an effective environmental challenge. The twenty or so cases that have gone to full trial—at a cost of about $10,000 each for scientific aid fees, lawyers, and expenses such as travel—have been plagued by economic problems, and except where scientists have been available through public agencies, few trials have been sophisticated.

One consequence is that most cases continue to focus on such familiar issues as subdivision development, road widening, and violations of existing regulatory standards; another is that plaintiffs are reluctant to challenge the biggest and most powerful interest groups in the state. Whatever disadvantages stemmed from forcing local citizen groups to foot the bill for using a law, there was at least one tactical advantage. Because the law did not pose a direct threat to the state's big industries, these groups never organized to undermine the statute during its formative periods. For almost five years, MEPA grew at its own pace. Well over 100 cases were initiated with the establishment of a substantial number of judicial precedents.

But MEPA's honeymoon could not last forever, and by 1975 the time was ripe for an attack on the statute by its opponents. The combination of fast-moving inflation and high unemployment invited a probe to see if the public continued to support environmental legislation. Many people in the state felt that the environmental movement as a political force was dead.

The test came with a lawsuit that used MEPA and involved the Upper Peninsula city of Marquette. The case itself was small stuff, but full of political dynamite. The Lake Superior and Ishpeming Railroad Company sought a permit to build a new coal-unloading dock, extending into Lake Superior near a part of Marquette that contained a local park and marina. Some local citizens led by Julia Tibbetts, an outspoken member of an old Marquette family, wanted to prevent what they viewed as the further industrialization of that part of the Lake Superior shoreline.

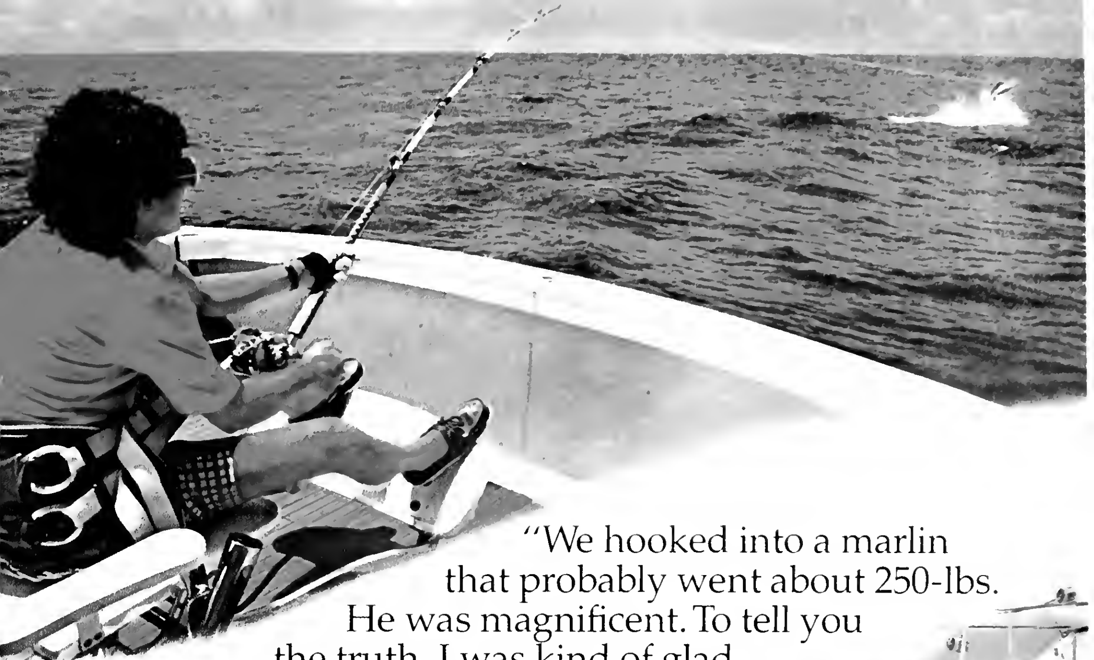
The dock was to be used to feed the local power plant, which was being expanded to supply energy for the rejuvenated iron-mining industry led by the Cleveland Cliffs Iron Company, a major stockholder of the railroad company. A challenge to the installation of the coal dock was seen as an attack upon the mining company.

The Upper Peninsula is one of the tragic places of the United States. Like Appalachia, but not so well publicized, it was stripped of its riches—iron, copper, and white pine forests—by aggressive outsiders and then left to suffer the burdens of abandonment. By the time World War I ended, the halcyon days of exploitation were over, and long decades of hard times, chronic unemployment, and welfare began. The environmental movement never exhibited much life in Marquette, and when worldwide economics and new technology began to make the reopening of iron mines a reality, the leadership in the Upper Peninsula encouraged unrestrained development.

In Lansing, the state capital, legislators from the Upper Peninsula were able to obtain exemptions for the mining industry from virtually every state environmental law. The water pollution statute, for example, contains a provision that baldly states, "This Act shall not be construed as applying to copper or iron mining operations." An almost identical provision was put into the soil erosion and sedimentation law, and there are exemptions for the mining industry in each of the basic water use and river management acts. The mining industry has even been authorized to invoke the state's power of eminent domain to acquire from private owners land to be used by mining companies as ore tailings disposal sites.

MEPA was the key piece of legislation from which the mining industry was not exempt, and with some nervousness, Upper Peninsula legislators watched the unfolding of Julia Tibbetts's lawsuit. In April 1975, the first of a series of bills designed to weaken MEPA was put forward in the legislature. While the Upper Peninsula holds only a tiny fraction of the state's population, it has a disproportion of legislators with the greatest seniority. The two principal advo-

(*Continued on page 21*)



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"Spring Melt"

(Continued from page 16)
cates of the bills—both Upper Peninsula legislators—were the chairman of the Appropriations Committee in the House of Representatives, the committee that controls all public monies, and the chairman of the Senate Conservation Committee, which has substantial jurisdiction over environmental legislation.

The old network of organizations that had lobbied to enact MEPA in 1970 now sought to reconstitute itself but discovered that while the organizations themselves still existed, the masses of volunteers had disappeared. In 1970, hundreds of college students appeared at environmental hearings; in 1975 no such constituency existed. A mailing campaign in 1970 had turned out 7,000 letters to a single legislator; five years later a similar campaign produced only a few hundred letters. An even more ominous sign lay in the Michigan AFL-CIO's defection from the pro-MEPA network to the Upper Peninsula legislators. At the same time, these legislators were importuning the most powerful member of the network, the United Auto Workers, to take a position "in favor of jobs."

Finally, over the five-year period there had been a large turnover in the composition of the legislature. The majority of those who had voted for MEPA were no longer in the capital. No more than a handful of the remaining legislators had deep personal commitments to environmental protection. There were a good number, however, who had no love for the mining industry or for the hard-driving legislators from the Upper Peninsula.

While the environmentalists were trying to adjust to the new facts of 1975, the Senate Conservation Committee approved a bill to weaken MEPA and the full senate quickly and quietly voted in favor of it. To make matters worse, the Upper Peninsula forces had persuaded a majority of House Conservation Committee members to vote to approve the bill over the chairman's objections. By midsummer, all that remained was a vote of the full house and the governor's signature.

August was a month of seeming despair. But the environmentalists still had some unplayed cards and a few unexplored strategies. One advantage was a combination of commitment and political expediency. The Upper Peninsula is represented by Democrats, and Governor Milliken is a Republican who had always supported MEPA. This battle gave him an opportunity to threaten to veto a Democrat-inspired attack on one of Michigan's most admired and progressive laws. For a governor who views himself as a forward-looking moderate, the veto threat was an attractive opportunity. Along with Milliken, the attorney general and the Department of Natural Resources never withdrew their support of MEPA.

Another source of hope was the United Auto Workers. They wavered but openly retained membership in the save-MEPA coalition. Between the UAW and the governor, neither the Republican nor the Democratic leadership in the house could give the bill support. And that meant that individual house members were going to have to stand by themselves and take a position. They could not take refuge in a mass party decision.

In the midst of this segmentation, the environmental coalition played its essential role. It had only one function—to make known to a substantial number of legislators that a good number of their constituents felt strongly that MEPA should not be tampered with.

Whether a core of a few thousand people existed who could be tapped to write, call, or visit legislators was unknown. The traditional technique, sending out a mail "alert" to organizational members, was abandoned. A telephone campaign was begun, using organizational membership lists and individuals who had already worked on behalf of MEPA in response to earlier appeals. This campaign paid off. Legislators began to receive large amounts of mail, perhaps 50 to 100 letters per day. The campaign also brought out a few MEPA supporters who were personal friends or financial supporters of influential legislators. These people were called on to obtain commitments against any last-minute defections, should the Upper Peninsula representatives try a final, backstage compromise. The message was clear. A lot of people cared about MEPA and opposition would be politically expensive.

The backers of the bill were not sitting still in the meantime. But their actions had the effect of self-entrapment. Their first proposal would have exempted from MEPA's influence anyone holding a valid permit to alter the environment. This would have had substantial impact all over the state, for a number of the early MEPA cases had demonstrated the vulnerability of many permits when subjected to environmental scrutiny. When it became clear that such a bill would be unpalatable to many legislators because it violated a right that their constituents valued, it was amended to provide exemptions for only the mining industry. This, of course, opened up new and fertile ground for opposition—the general distaste for special interest legislation.

The newspapers condemned the new proposal even more vehemently than they had criticized the old. The vast majority of Michigan newspapers outside the Upper Peninsula editorialized frequently and vigorously in support of preserving MEPA. Their support was indispensable in the battle to save the statute.

By autumn it began to look as if MEPA would be saved after all. But the persistent Upper Peninsula legislators were able to keep their bill alive for months. If a vote went against them, they would arrange to have it reconsidered at a later date. They would then begin a new round of lobbying, modifying the text of the bill with claims that previous flaws had been corrected. Probably they hoped to win a war of attrition against the few environmental lobbyists, most of whom were amateurs.

This tactic also backfired. For as long as the bill was alive, legislators continued to receive adverse mail. Finally, almost everyone realized that the politically savvy solution was to dispose of the bill; it only seemed to produce a bad press and critical mail. The house finally voted to substitute an amendment that gave MEPA cases priority on the court calendars—a noncontroversial change that would have simply expedited litigation. That bill was sent to a house-senate conference where it appears to have died a quiet and informal death over the Christmas recess.

When the legislature reconvened in early 1976, no one was surprised when the indefatigable Conservation Committee chairman, Sen. Joe Mack of the Upper Peninsula, introduced yet another version of a bill to scuttle MEPA. But no one gave it serious attention. The word in Lansing is that the environmental movement, at least for the moment, is still a force to reckon with. □

by Jay W. Forrester

Limits to Growth Revisited

A second look at how, when, and by what processes growth will end

Following the publication in 1972 of *The Limits to Growth,* the press and many symposia debated issues arising from industrial growth. But much of the debate has missed the most important central issue. Attention has focused on physical limits and on whether or not the physical limits to growth can be overcome, carrying with it the implication that if physical limits can be overcome then the problems are solved. The problem does not lie alone in physical limits but also in social limits.

The physical and social limits to growth are very closely coupled. Production has been growing for centuries at a more or less exponential rate. In exponential growth, doubling recurs within some fixed length of time. Recently, physical output in the United States has been doubling about every twenty years, while population has been doubling somewhat more slowly. The rising standard of living comes from the difference in those doubling periods, with output doubling in a shorter period than population. But exponential growth cannot continue forever. If the present world population were to continue doubling every 30 years, the entire land surface of the earth would reach standing room only in 350 years. At some point, growth must level into equilibrium.

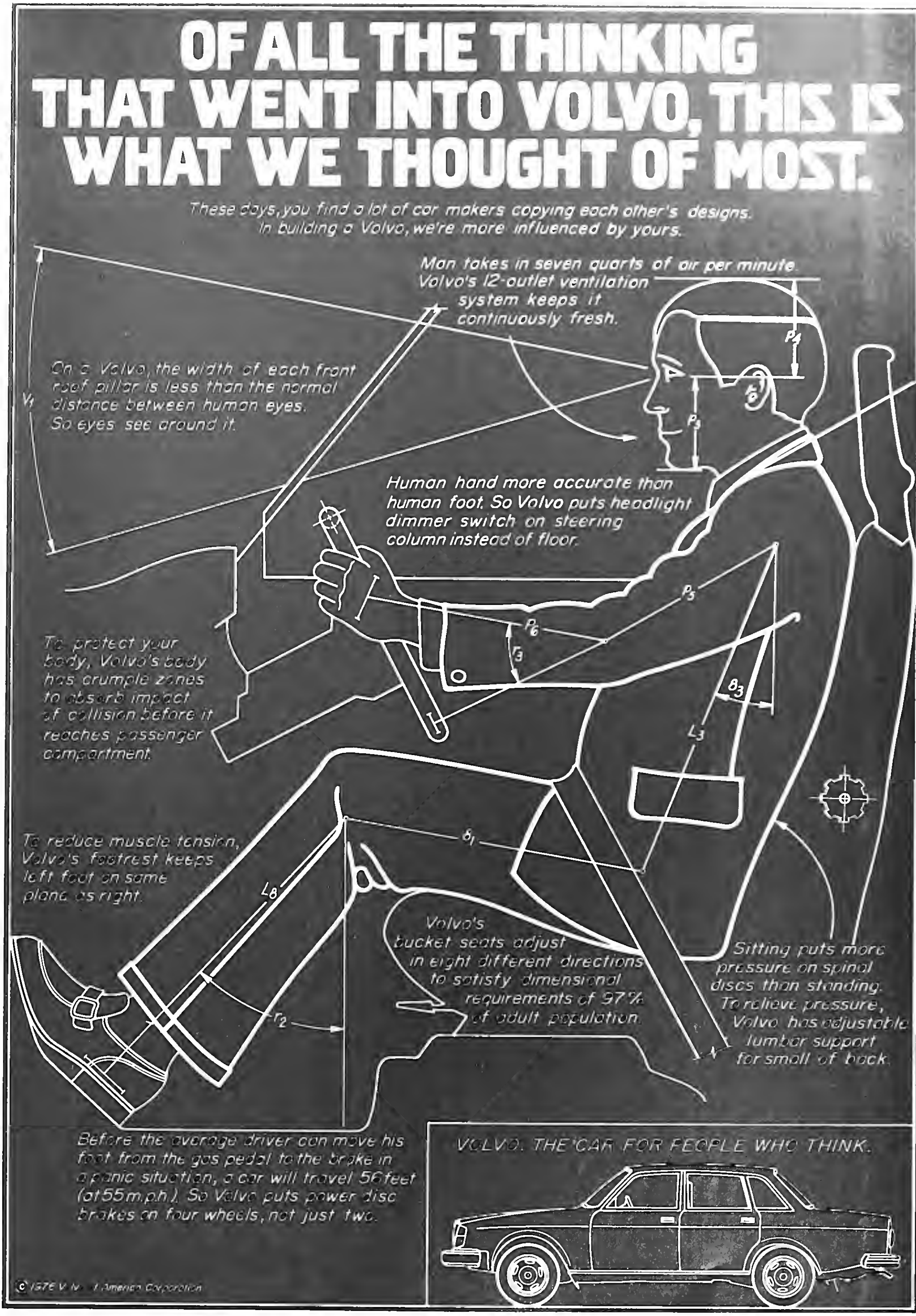
There is almost no disagreement over the ultimate end of exponential growth. The debate is over how, when, and by what processes growth will end. I will discuss here the transition stage—the interval between the growth stage and equilibrium—in which the upward curvature of production gives way to equilibrium or to peaking and decline. A point of inflection exists in the middle of the transition stage where the curvature changes because sufficiently great forces are generated in society at that time to overcome the old mode of growth. The old traditions, the old attitudes, and the old economic processes are overwhelmed.

It is in the transition region—halfway up the growth curve—that the greatest social stresses occur, not out in equilibrium at the end of the growth life cycle. In the transition region the pressures become great enough to change the style and mode of the social system from upward curvature to downward curvature. I believe we are now in that transition period. One more doubling would carry growth to some upward limit even though tens of doublings in the past have brought us only to the halfway point. In other words, it takes hundreds of years to come the first half of the way, and only one more doubling for the second half. The great forces countering growth exert their influence over a relatively short period. We are caught unawares by the sudden appearance of economic and social forces, even though they are inherent in the structure of the system in which we live.

In the transition region, the dynamics of the goal structure of a society begin to change, particularly the way in which goals interact with one another. In the growth mode, there was plenty of space—geographical space, environmental space, psychological space, legal space, social space—and one aspect of the society impinged only slightly on other aspects. It was possible during growth to pursue the separate goals of the society independently.

For several hundred years, if we could improve each part of the system, we improved the system in its entirety. We have a multiplicity of subgoals that we have been pursuing independently. We developed public health measures to improve health, not worrying about the consequence of rising population because population could move into new lands. Tractors could increase food production and the required energy would simply come from oil wells. Each goal could be separately pursued. But in the transition region, the goals become interlocked and interdependent. For the first time, the interrelationships between technology, economics, politics, and even ethics and freedom become very tight. The many goals impinge on one another in a way that we have not experienced before.

We have seen some recent examples of interaction between goals. Becoming disturbed about pollution from automobiles, we redesigned engines, increased gasoline consumption, created a fuel shortage, and generated international political stresses—all within five years. Medical advances have increased population, leading to the population problem and to food shortage. The engineering victories of high-rise buildings have concentrated population, increased psychological stress and crime, and reduced personal free-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dom. So, technology, freedom, and every other aspect of society become highly interlinked in the transition region.

The consequence of independent goal seeking during the transition stage can be quite unexpected. Improvement may not occur in the goal being sought; instead, degradation may result elsewhere. For example, in seeking a goal of better housing in a city, government may build low-cost housing, attract scores of occupants, increase the number of people relative to jobs, and end up with more unemployment. Or, if we grow more food in an attempt to reduce hunger, this may only lead to more people, the same percentage of the population hungry, and social unrest from crowding. More food leads to more population, not to less average hunger. In the transition region, such compensating side effects tend to defeat the pursuit of subgoals.

A simplified relationship between population, environment, and technology indicates that rising population leads to increased pressure on the environment, which stimulates further demand for engineering to relieve pressures, which, in turn, encourages additional population. Technology made large populations possible, and large populations make advanced technology necessary. A feedback loop operates in which population requires technology, technology makes more population possible, and the rising population puts still greater demands on technology. The process can recirculate as long as no limits appear from land shortage, overcommitment of pollution dissipation capacity, food deficiencies, or water shortages. The process continues until it either encounters physical limits or moves into social limits.

At some point in the growth process, which many countries seem to be reaching, we find that crowding transfers stresses from the physical realm to the social. Social stresses manifest themselves in rising crime rates, drug addiction, aircraft hijackings, kidnappings, mental illness, psychological trauma, community breakdown, genocide, revolutions, and war. Social breakdown becomes more likely as we put stresses on the social fabric of society. More and more persons are pulled away from producing goods and food and enter government, law, negotiation, and arbitration to cope with the social complexities that come with the filling up of physical and psychological space.

We must balance physical stresses against social stresses. Furthermore, we must choose a balance between direct forces limiting growth rate and the indirect forces of self-restraint in control of growth. We can control growth through the channel of self-restraint by foreseeing physical stress and slowing growth or by foreseeing social stress and slowing growth. Otherwise, growth continues until either physical or social stress directly stops growth—physical stress in the sense of starvation or social stress in the sense of breakdown of social stability. There are several channels for creating equilibrium in the future. The choice of continued growth is not open for long. We must choose one of the restraint channels or the system will choose for us a direct application of physical or social force.

The fundamental question in most countries is the balance to be struck between population and the standard of living. The pursuit of technology may divert us from facing the fundamental question of limiting population to both the physical and social limits of the environment. We are apt to believe that if we can solve the technological problems, we will have solved all of our problems. In fact, the removal of technological limits will merely shift the burden of restraint to the social limits. Do we want a distributed set of pressures or do we want pressures from one direction only? I believe that pressures from social stress only will be more disruptive and dangerous than pressures distributed over both the social and physical limits.

The question is not can science remove the physical limits? Science probably can. Rather we should ask, do we want science to remove the physical limits? An affirmative answer is equivalent to saying we want growth to be arrested by social stress alone. When put that way, it is far from obvious that we wish to solve the technological limits and thereby raise the level of stress in the social area.

Jay W. Forrester teaches management at Massachusetts Institute of Technology. This article is taken from a speech he made at the Franklin Institute in Philadelphia. Copyright © 1974 by Jay W. Forrester.

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This View of Life by Stephen Jay Gould

The Five Kingdoms

The simplistic classification of life into plants and animals ignores the history and importance of single-celled organisms

When I was ten years old, James Arness terrified me as a giant, predacious carrot in *The Thing* (1951). Two hours ago—older, wiser, and somewhat bored—I watched its latest television rerun and this time anger dominated my reaction. I recognized the film as a political document, expressing the worst sentiments of America in the cold war. Its hero, a tough military man, wants only to destroy the enemy; its villain, a naïvely liberal scientist, wants to learn more about it; the carrot, along with its flying saucer, is a certain surrogate for the red menace; and the film's impassioned last words—"watch the skies"—are an invitation to extended fear and jingoism.

Amidst all this, a scientific thought crept in by analogy—the fuzziness of all supposedly absolute taxonomic distinctions—and this column was born. The world, we are told, is inhabited by animals with conceptual language (us) and those without (everyone else)—but chimps are now talking. All creatures are either plants or animals, but Mr. Arness looked rather human (if horrifying) in his role as a mobile, giant vegetable.

Either plants or animals. Our basic conception of life's diversity is based upon this division. Yet it represents little more than a prejudice spawned by our status as large, terrestrial animals. True, the macroscopic organisms surrounding us on land can be unambiguously allocated if we designate fungi as plants because they are rooted (even though they do not photosynthesize). Yet, if we floated as tiny creatures in the oceanic plankton, we would not have made such a distinction. At the one-celled level, ambiguity abounds: mobile "animals" with functioning chloroplasts; simple cells like bacteria with no clear relation to either group.

Taxonomists have codified our prejudice by recognizing just two kingdoms for all life—Plantae and Animalia. But isn't inadequate classification a trifling matter? After all, if we characterize organisms accurately, who cares if the basic taxonomic categories do not express the richness and complexity of life? But a classification is not a neutral hat rack; it expresses a theory of relationships that controls our concepts. The Procrustean system of plants and animals has distorted our view of life and prevented us from understanding some major features of its history.

Seven years ago, Cornell ecologist R. H. Whittaker proposed a five-kingdom system for the organization of life (*Science*, January 10, 1969); his scheme has recently been championed and expanded by Boston University biologist Lynn Margulis in the latest issue of *Evolutionary Biology*. Their criticism of the traditional dichotomy begins among the single-celled creatures.

Anthropocentrism has a remarkably broad range of consequences, ranging from strip mining to whale killing. In folk taxonomy it leads us to make fine distinctions among creatures close to us and very broad ones for more distant, "simple" organisms. Every novel bump on a tooth defines a new kind of mammal, but we tend to lump all single-celled creatures together as "primitive" organisms. Nonetheless, specialists are now arguing that the most fundamental distinction among living things is not between "higher" plants and ani-

mals; it is a division *within* single-celled creatures—bacteria and blue-green algae on the one side, other groups of algae and protozoans (amoebae, paramecia, and so on) on the other. And neither group, according to Whittaker and Margulis, can be fairly called either plant or animal; we must have two new kingdoms for single-celled organisms.

Bacteria and blue-green algae lack the internal structures, or "organelles," of higher cells. They have no nucleus, chromosomes, vacuoles, chloroplasts, or mitochondria (the "energy factories" of higher cells). Such simple cells are called "prokaryotic" (roughly, before nuclei, from the Greek *karyon,* meaning "kernel"). Cells with organelles are termed "eukaryotic" (truly nucleate). Whittaker considers this distinction "the clearest, most effectively discontinuous separation of levels of organization in the living world." Three different arguments emphasize the division:

1. The history of prokaryotes. Our earliest evidence of life dates from rocks about three billion years old. From then until at least one billion years ago, all fossil evidence points to the existence of prokaryotic organisms only; for two billion years, blue-green algal mats were the most complicated forms of life. Thereafter, opinion differs. UCLA paleobotanist J. W. Schopf believes that he has evidence for eukaryotic algae in Australian rocks about a billion years old. Others contend that Schopf's organelles are really the postmortem degradation products of prokaryotic cells. If these critics are right, then we have no evidence for eukaryotes until the very latest Precambrian, just before the great Cambrian "explosion" of 600 million years ago (see my column of November 1974). In any case, prokaryotic organisms held the earth as their exclusive domain during two-thirds to five-sixths of the history of life. With ample justice, Schopf labels the Precambrian as the "age of blue-green algae."

2. A theory for the origin of the eukaryotic cell. Margulis has stirred a great deal of interest in recent years with her modern defense of an old theory, which sounds patently absurd at first but quickly comes to compel attention, if not assent. I am certainly rooting for it. Margulis argues that the eukaryotic cell arose as a colony of prokaryotes—that, for example, our nucleus and mitochondria had

their origins as independent prokaryotic organisms. Some modern prokaryotes can invade and live as symbionts within eukaryotic cells. Most prokaryotic cells are about the same size as eukaryotic organelles; the chloroplasts of photosynthetic eukaryotes are strikingly similar to the entire cells of some blue-green algae. Finally, some organelles have their own self-replicating genes, remnants of their formerly independent status as entire organisms.

3. The evolutionary significance of the eukaryotic cell. Advocates of contraception have biology firmly on their side in arguing that sex and reproduction serve different purposes. Reproduction propagates a species, and no method is more efficient than the asexual budding and fission employed by prokaryotes. The biological function of sex, on the other hand, is to promote variability by mixing the genes of two (or more) individuals. (Sex is usually combined with reproduction because it is expedient to do the mixing in an offspring.)

Major evolutionary change cannot occur unless organisms maintain a large store of genetic variability. The creative process of natural selection works by preserving favorable genetic variants from an extensive pool. Sex can provide variation on this scale, but efficient sexual reproduction requires the packaging of genetic material into discrete units (chromosomes). Thus, in eukaryotes, sex cells have half the chromosomes of normal body cells. When two sex cells join to produce an offspring, the original amount of genetic material is restored. Prokaryotic sex, on the other hand, is infrequent and inefficient. (It is unidirectional, involving the transfer of a few genes from a donor cell to a recipient.)

Asexual reproduction makes identical copies of parental cells, unless a new mutation intervenes to yield a minor change. But new mutation is infrequent and asexual species do not maintain enough variability for significant evolutionary change. For two billion years, algal mats remained algal mats. But the eukaryotic cell made sex a reality; and less than a billion years later here we are—people, cockroaches, seahorses, petunias, and quahogs.

We should, in short, use the highest taxonomic distinction available to recognize the difference between prokaryotic and eukaryotic single-celled organisms. This establishes two king-

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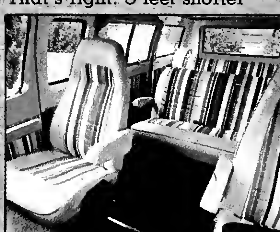

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doms among one-celled creatures: Monera for the prokaryotes (bacteria and blue-green algae); Protista for the eukaryotes.

Among multicellular organisms, Plantae and Animalia remain in their traditional senses. Whence, then, the fifth kingdom? Consider the fungi. Our Procrustean dichotomy forced them into Plantae, presumably because they are rooted to a single spot. But their resemblance to true plants stops with this superficial feature. Higher fungi maintain a system of tubes superficially like those of plants; but while nutrients flow in plants, protoplasm itself courses through the fungal tubes. Many fungi reproduce by combining the nuclei of several individuals into a multinucleate tissue without nuclear fusion. The list could be extended, but all its items pale before one cardinal fact: fungi do not photosynthesize. They live embedded in their food source and feed by absorption (often by excreting enzymes for external digestion). Fungi, then, form the fifth and final kingdom.

As Whittaker argues, the three kingdoms of multicellular life represent an ecological, as well as a morphological, classification. The three major ways of making a living in our world are well represented by plants (production), fungi (reduction), and animals (consumption). And, as another nail in the coffin of our cosmic arrogance, I hasten to point out that the major cycle of life runs between production and reduction. The world could get along very well without its consumers.

I like the five-kingdom system because it tells a sensible story about organic diversity. It arranges life in three levels of increasing complexity: the prokaryotic unicells (Monera), the eukaryotic unicells (Protista), and the eukaryotic multicells (Plantae, Fungi, and Animalia). Moreover, as we ascend through the levels, life becomes more diverse—as we should expect since increasing complexity of design begets more opportunity for variation upon it. The world contains more distinctively different kinds of protistans than monerans. At the third level, diversity is so great that we need three separate kingdoms to encompass it. Finally, I note that the evolutionary transition from any level to the next occurs more than once; the advantages of increased complexity are so great that many independent lines converge upon the few possible

solutions. The members of each kingdom are united by common structure, not by common descent. In Whittaker's view, plants evolved at least four separate times from protistan ancestors, fungi at least five times, and animals at least three times (the peculiar mesozoans, sponges, and everything else).

The three-leveled, five-kingdom system may appear, at first glance, to record an inevitable progress in the history of life that I have often opposed in these columns. Increasing diversity and multiple transitions seem to reflect a determined and inexorable progression toward higher things. But the paleontological record supports no such interpretation. There has been no steady progress in the higher development of organic design. We have had, instead, vast stretches of little or no change and one evolutionary burst that created the entire system. For the first two-thirds to five-sixths of life's history, monerans alone inhabited the earth, and we detect no steady progress from "lower" to "higher" prokaryotes. Likewise, there has been no addition of basic designs since the Cambrian explosion filled our biosphere (although we can argue for limited improvement *within* a few designs—vertebrates and vascular plants, for example).

Rather, the entire system of life arose during about 10 percent of its history surrounding the Cambrian explosion some 600 million years ago. I would identify two main events: the evolution of the eukaryotic cell (making further complexity possible by providing genetic variability through efficient sexual reproduction) and the filling of the ecological barrel by an explosive radiation of multicellular eukaryotes.

The world of life was quiet before and it has been relatively quiet ever since. The recent evolution of consciousness must be viewed as the most cataclysmic happening since the Cambrian if only for its geologic and ecological effects. Major events in evolution do not require the origin of new designs. The kingdom of flexible eukaryotes will continue to yield novelty and diversity so long as one of its latest products controls itself well enough to assure the world a future.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

A $135 Million Gamble

by Edwin D. Kilbourne

Swine influenza's death-dealing past makes the decision to stem it more than a political one

The epidemiology of most viruses in man is fairly predictable based on their relatively stable characteristics, a result of an obligate adaptation to human hosts over thousands of years. From an anthropocentric viewpoint, viruses can be viewed as predators because their survival depends upon their capacity to attack and secure nutrients from the bodies of their victims. More sophisticated than most predators, their self-perpetuation usually can be achieved without killing those they attack.

Several years ago in this magazine (January 1973) I described influenza virus as an "adaptable predator" and emphasized its changeable nature. In recent years, worldwide influenza epidemics have occurred approximately every decade (1946, 1957, 1968) and have always followed the emergence of major antigenic variants of influenza A, very different from the virus that had just previously circulated in the human population.

These major, or pandemic, variants of influenza virus may originate in animals—particularly in domestic species in close contact with man. One such species is swine, which does harbor influenza A, but of a type different from known human strains. Such influenza viruses in animals, however, are rarely transmitted to man and appear to be restricted to their specific hosts. If this is true, how can these viruses cause potential pandemics in man? The answer may lie in the capacity of human and animal influenza viruses to interact genetically—a capacity that could endow the animal virus with genes necessary for its transmission and replication in man. Studies in lower animals have provided evidence on this point.

When an influenza epidemic that broke out in February at Fort Dix, New Jersey—killing one person and infecting hundreds of others—was found to have been caused by a virus indistinguishable from swine influenza virus, a chain of controversial events began. The result was that within a few weeks the president proposed and Congress approved a mass immunization campaign that will cost $135 million for the purchase of 200 million doses of swine influenza virus vaccine. To many, this decision,

Measures to alleviate the 1918 influenza pandemic, which killed more than 500,000 people in this country, included laws that prohibited sneezing in public places and required the wearing of face masks. In accordance with the latter, Chicago street cleaners line up for inspection.

United Press International

seemingly based on sketchy evidence, was difficult to understand; at the very least, it appeared to be an extreme overreaction to a minor threat. What then was the basis for the vaccine decision and for the concern behind it?

Although at the time of the decision infection with swine influenza virus appeared to have been limited to soldiers at Fort Dix, this alone indicated that the swinelike virus is clearly transmissible from human to human. On indirect but substantial evidence, the cause of the notorious 1918 pandemic of influenza was a virus similar in its surface antigens to the Fort Dix virus. Some students of influenza believe that the 1918 virus, which caused 20 million deaths, was uniquely virulent, although most of the fatalities probably resulted from secondary bacterial pneumonia. Although the Fort Dix experience presented no evidence of exceptional virulence of the virus, further transfer of the virus could augment its virulence in future epidemics. The second wave of influenza in 1918 was more devastating than the first, but this cannot necessarily be ascribed to change in the intrinsic virulence of the virus.

The world population is virtually devoid of antibody, and hence immunity, to the swine influenza virus, except for those who were exposed to the 1918 virus during the period from 1918 to 1929 and who therefore are more than 47 years of age. This lack of immunity indicates that the swine influenza virus is different from all but the 1918 human strains and represents a major mutation of the virus to a different subtype. This is a cardinal reason for concern because in the past, mutations in the virus of this degree have always been followed by pandemic spread of the new virus as it replaced the old. We are nearing the end of a decade of prevalence of Hong Kong-like influenza virus; the disappearance of that virus and the emergence of some major new variant had been expected, although the exact nature of the variant seemed unpredictable. At least two groups of investigators, however, had predicted the reappearance of the swine virus on the basis of recent recycling of other past influenza virus antigens. The basis of concern at this time is primarily the marked difference of the Fort Dix virus from present human strains, rather than its "swinelike" nature per se.

The Fort Dix swine influenza virus

probably did not originate at Fort Dix but was imported from other areas. Indeed, the family of one soldier from Pennsylvania was found to have acquired antibodies to the virus in the absence of contact with swine. The epidemiology of influenza is such that sequential infections, sometimes without symptoms, occur throughout the year, but recognizable epidemics are principally winter phenomena. The Fort Dix virus may persist unrecognized in the human population until the fall or winter.

Those who advised the president and the Congress to appropriate funds for the development of a vaccine based their decision not only on these concerns but also on the following:

First, for the first time in history the early recognition of a major viral mutant provides the opportunity to modify the course of an incipient pandemic. Second, although presently available influenza vaccines do not produce permanent immunity, they are from 70 to 90 percent effective over one- to two-year periods. Third, influenza vaccines are preparations of inactivated virus that generally are well tolerated and without serious side effects. And fourth, officials of the Bureau of Biologics—the regulators of vaccine control and licensure—established that production of 200 million doses of vaccine by the fall/winter of 1976 was possible. The feasibility of production depended on the availability of a laboratory hybrid of the Fort Dix virus that would grow well in chicken embryos in which vaccine is produced. A virology laboratory promptly produced this virus.

Yet with all the foregoing considerations in mind, one must admit the possibility that the Fort Dix outbreak was a freak occurrence, that further transmission of virus may not occur, and that millions of people will be unnecessarily subjected to vaccination against a pandemic that will not come. But if one waits for further evidence of spread, then it will be too late to immunize the population for the winter of 1976–77, and once again we shall stand idly by as influenza kills thousands and incapacitates millions at an economic cost of billions. To some of us, the vaccine decision seemed inescapable and the president and the Congress, on the basis of this advice, have concurred.

Edwin D. Kilbourne is chairman of the Department of Microbiology at the Mount Sinai School of Medicine.

First Prize

Macro/Microphotography
Wild honeycomb
O'Hara Township, Pennsylvania
Virginia A. Phelps

The Perceptive Eye

The prizewinning photographs from the 1976 Natural History Photographic Competition . . . and the categories for the 1977 competition

In the opening pages of *Walden*, Thoreau chides his friends and readers for being impressed by the exotic, while failing to observe their own environs. He introduces the section with the comment, "I have traveled a good deal in Concord."

The winners of the 1976 *Natural History Photographic Competition* have traveled a good deal in their home towns too. As we looked through the prizewinning photographs, we were struck by the general absence of foreign scenes, exotic animals, and unusual subjects. And as we talked to the prizewinners themselves, one consistent theme emerged: "Oh, I photographed the tree in a nearby park"; "The plant was growing on a dirt road near my house"; "The shell was on a beach where we often camp"; "I thought I'd see what an ordinary chrysanthemum leaf looks like." Although these comments often had a defensive ring, they suggest that more and more people are coming to understand that photography, like any art form, is not only a way of recording the spectacular and unusual but also a way of seeing a subject and communicating feelings about it.

This viewpoint was summarized by several prizewinners, including one who expressed his plan to put a time-lapse camera in his window for a year. Stephen Diehl, talking about his closeup view of an apple leaf with ice crystals, commented that he does a great deal of macrophotography because the area where he lives—Rochester, New York—does not offer spectacular scenes. Being forced to get close to his subject, he must "feel first, fantasize on a minute level. It's there if you believe it to be."

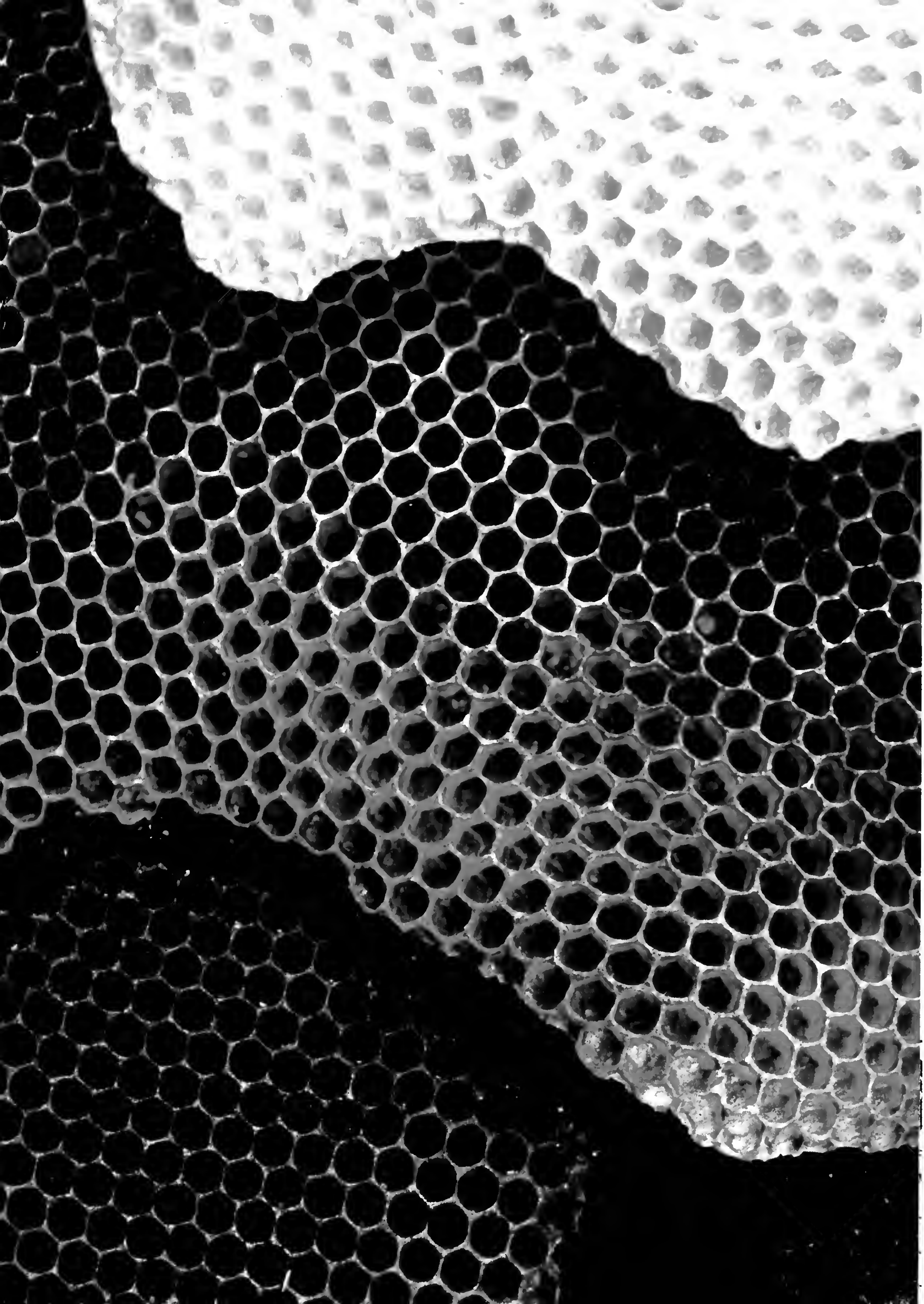
Echoing these views, Vici Zaremba observed that "there is so much to see in one place. I go back to a spot and keep finding things changing. People don't take enough time to look, especially in winter." Her Honorable Mention picture of a snow-covered spruce tree was taken in Mendon Ponds, a county park outside Rochester, which she visits frequently.

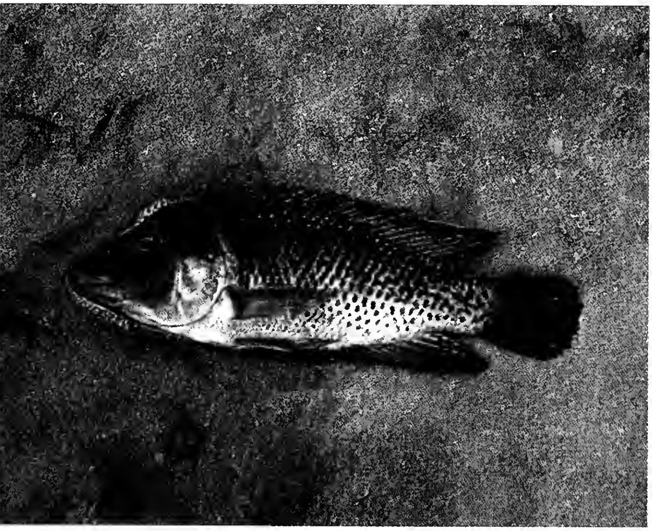
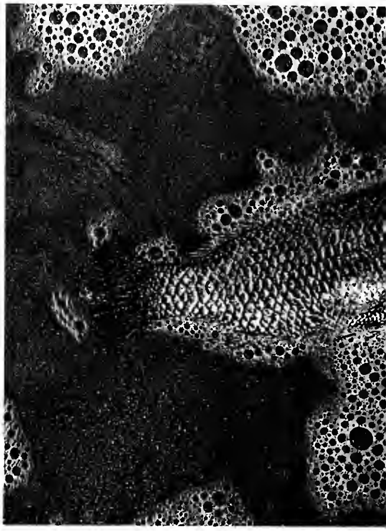
Other prizewinners commented that as a result of taking pictures, they have learned to see more. One described the process as that of a laser beam focusing on a subject. John Sackett became involved with several generations of a black family through his photographic experiences. While taking pictures of the children, the father, and finally the grandmother—his prizewinning photograph—he developed a rich insight into their feelings and traditions. Virginia Phelps, whose photograph of wild honeycomb won First Prize in the Macro/Micro Category, always has her camera with her and feels that photography enhances her involvement with the environment. Intensely interested in wildflowers, she has been a volunteer in botany and photography at Shenandoah National Park for many years.

Like Virginia Phelps—who made a special trip to a friend's farm to photograph the wild beehive—Nancy Benham drove especially to a canyon near her Carmel, California, home because she had heard that some trillium was growing there. She found two specimens, the first she had ever seen, and her elegant photograph of the plant earned Grand Prize in the competition.

For Thomas Wiewandt, a graduate student who is studying the ecology and behavior of the ground

(*Continued on page 59*)



First Prize

A Chronological Sequence
of an Event in Nature
Stages of decay of a tilapia fish
Lago Enriquillo, Dominican Republic
Thomas A. Wiewandt

First Prize

The Natural World
Young elephant and elders
Tsavo East National Park, Kenya
Nadine Bertin Stearns

Overleaf
Grand Prize

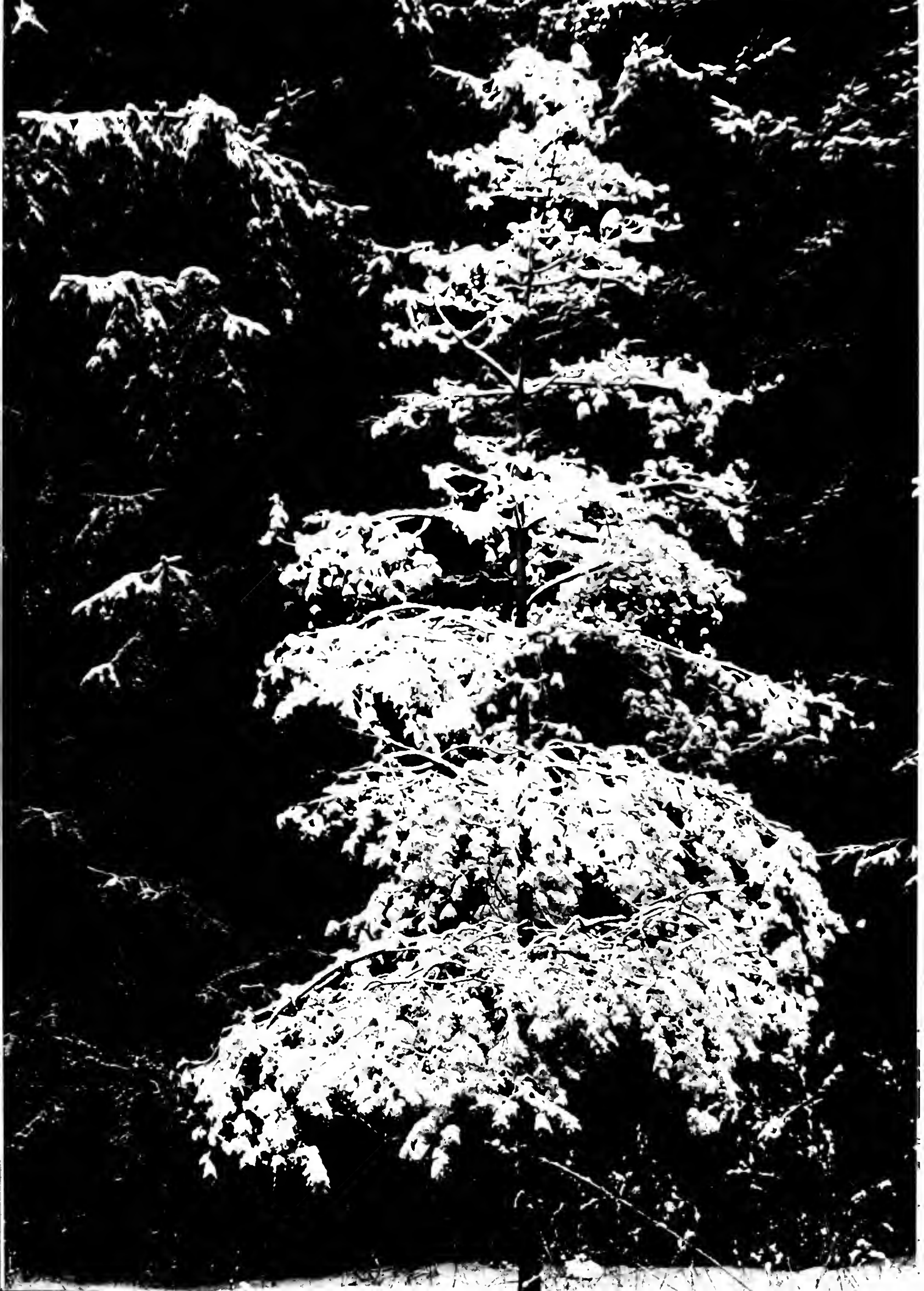
Trillium
Big Sur, California
Nancy Benham

Honorable Mention
Apple leaf
Rochester, New York
Stephen J. Diehl

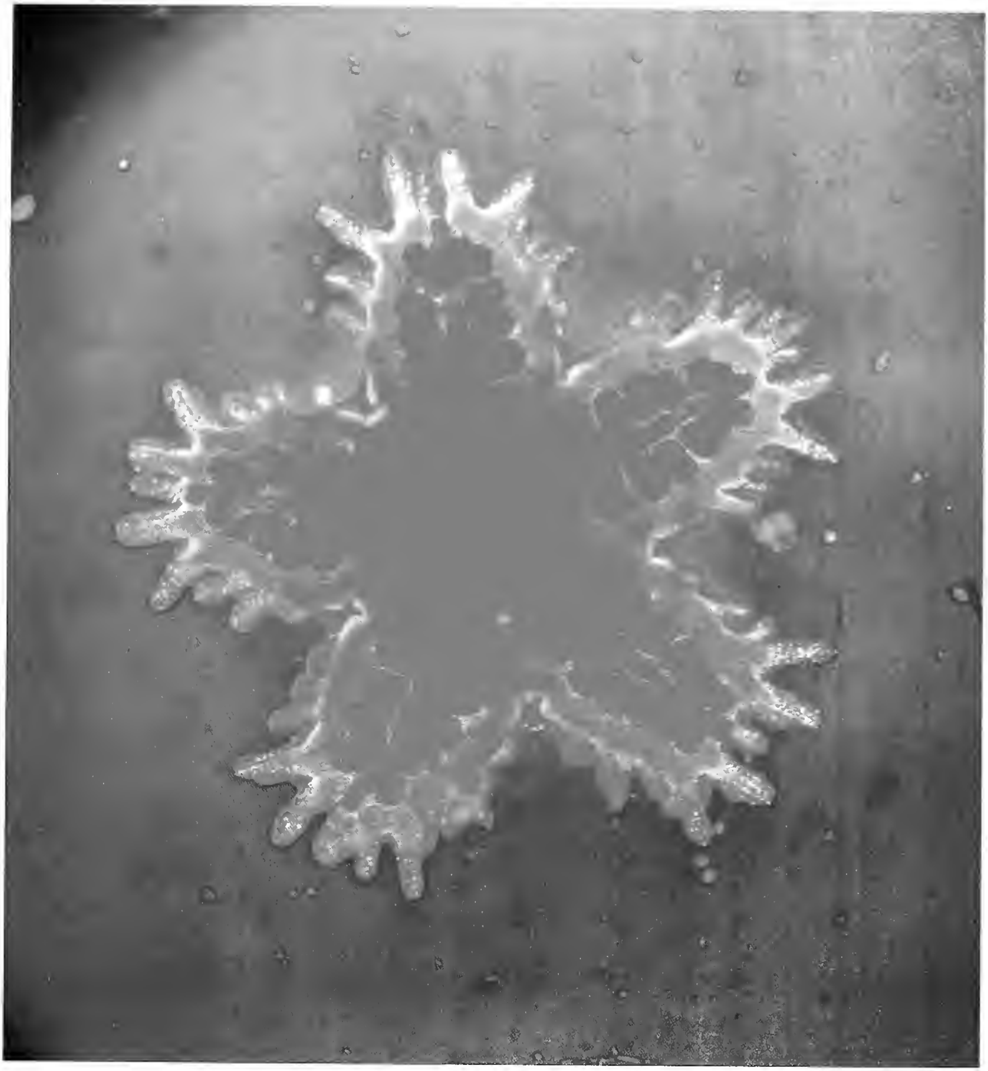
Honorable Mention
Clamshell on beach
Baja California, Mexico
Dorothy A. Todd

Honorable Mention
Snow-covered spruce tree
Rochester, New York
Vici Zaremba

Honorable Mention
Katmandu Bazaar
Katmandu, Nepal
James Kittle

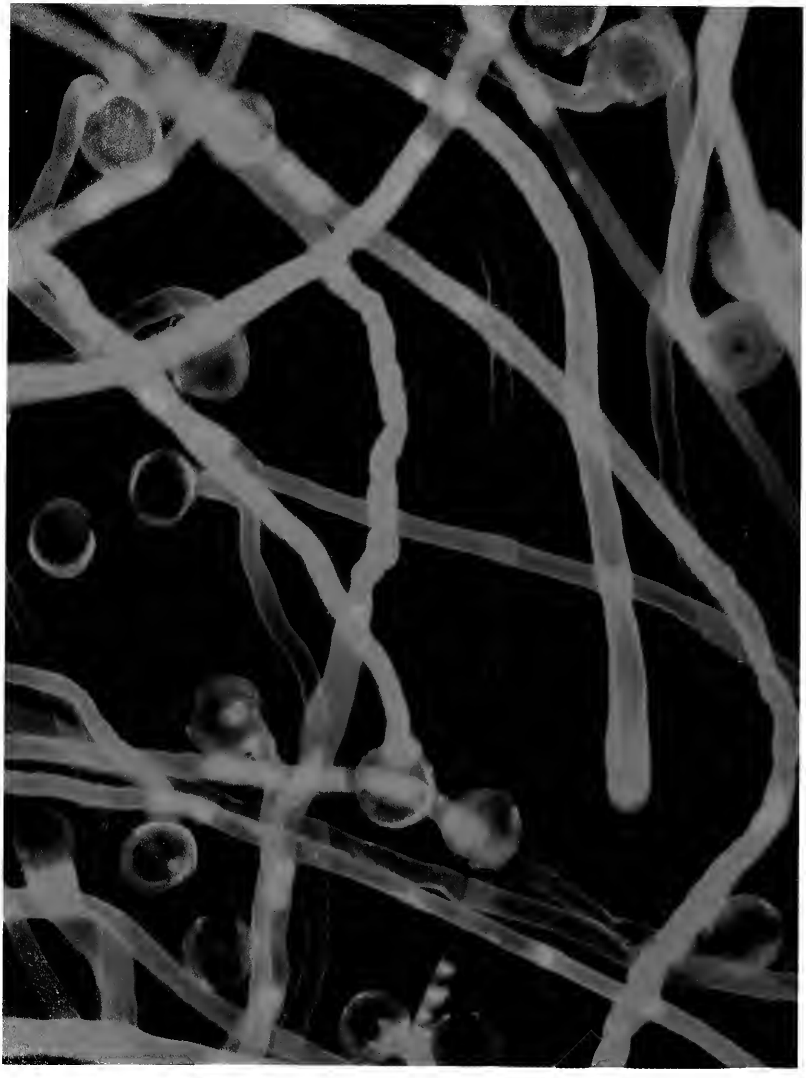


Honorable Mention
Mrs. Goodwin
Houston, Texas
John D. Sackett



Honorable Mention
Starfish larva
Photographed at 40X
Lester V. Bergman

Honorable mention
Resorcinol crystals
Photographed at 35X
Lawrence Schauffler



Honorable Mention
Germinating pollen tubes of lily,
Photographed at 125X
Sanat K. Majumder

Honorable mention
Upper leaf surface of chrysanthemum
Scanning electron microscope
Photographed at 220X
James R. Swafford

(*Continued from page 42*)
iguana, photography serves an esthetic as well as a documentary function. He finds that motion pictures are a great help in interpreting subtle behavior, but he uses still photographs for comparison and for answers to less obvious research questions. Wiewandt was, in fact, surveying Lago Enriquillo in the Dominican Republic for iguanas when he took his First Prize-winning sequence of decaying fish. In addition to portraying a stunningly imaginative sequence, his pictures tell an ecological story. The lake, cut off from the sea during the Pleistocene, is supersaline, with nearly double the salt concentration of seawater. Because of a hurricane some years ago, a smaller lake has flooded into Lago Enriquillo, bringing with it many freshwater species, such as the tilapia fish, that are unable to survive the saline concentration. In his depiction of decay and regeneration, Wiewandt has "speeded up" a natural process that would take months or possibly years, photographing five fish at five sites in one day.

Although other prizewinners also use photography in their work, they felt their entries were not only scientifically interesting but beautiful as well. James Swafford, a microbiologist at Arizona State University, uses the scanning electron microscope in his research on morphology of unusual organisms and in collaborative studies with botanists who are analyzing desert plants. He also teaches a graduate-level course in electron microscopy. Yet his photograph of the upper leaf surface of a chrysanthemum was taken, as Swafford put it, "for its sheer beauty." He was fascinated by the propellerlike patterns.

Lawrence Schauffler photographed ordinary crystals bought in a drugstore; through his pictorial interpretation, however, they have an impressionistic quality. Schauffler began his microscopic work three years ago at the age of eighty, as a way of continuing his interest in photography now that he is unable to travel a great deal.

One of the few professional photographers among the prizewinners, Lester Bergman specializes in scientific work. He has illustrated surgical texts, made films of microscopic images, and is responsible for time-lapse advertising films that show greasy spots being washed out of a new white jacket. His photograph of a starfish larva, however, was a "self-assignment in enlivening the microscopic image." He used a purchased specimen, then worked at the microscope in his laboratory until he had the picture he wanted.

Overwhelmingly, the prizewinning photographs reveal a quality of thoughtfulness. Few were inherently "great shots" or the kind of scene that appears for only an instant. Rather, the photographs the judges selected show visual imagination, interpretation, and involvement. While this was more apparent in the seemingly ordinary subjects shot close to home, such personal involvement can also be seen in the photographs that resulted from foreign travel. According to James Kittle, whose photograph of a woman at the Katmandu bazaar won Honorable Mention, "It would be hard to take a bad picture in Nepal." Yet Kittle does more than merely take a good picture; he brings a human dimension to his photograph. Impressed by Nepal, by the faces of its people, the smells and colors at its markets, he conveys all these feelings in his photograph.

Nadine Bertin Stearns, too, combines emotion with an excellent sense of composition in her photograph taken at Tsavo East National Park in Kenya. She has always been involved with animals, but feels a particular tenderness for elephants. Her First Prize-winning photograph—showing a young animal amongst elders—mirrors the disparity between the elephants' size and their gentleness, the concern of the big caring for the little.

At a time when depressed economic conditions are restricting travel, when the brightness of the environmental movement seems tarnished, and when Bicentennial fervor is either turning people away from the present to a sentimentalized past or turning them off altogether, the results of this year's photography contest are particularly satisfying. In addition to the fourteen prizewinning photographs, the thousands of other entries demonstrated that people are becoming increasingly sensitive to their environments. Whether on weekend outings, behind the microscope, or walking to work, they, like Thoreau, are traveling a good deal.

Prizes for the competition are: Grand Prize, $500; First Prize, $250; Honorable Mention, $100. In addition, the prizewinning photographs will be displayed at a special exhibition at The American Museum of Natural History.

And next year: The categories for the 1977 Photographic Competition (details to be announced in future issues) are The Natural World, A Chronological Sequence of a Natural Event, Microphotography, and The Human Family. Special awards for Humor and Urban Wildlife.

Toni Gerber

Return to Manus

by Margaret Mead

Reo Fortune

Theodore Schwartz

Theodore Schwartz

After a half century of troubled growth, a New Guinea village is finding its identity in a blend of tradition and development

"Did anyone remember you?" people asked me when, in 1953, I said I had returned from Pere, the little Manus village in the Admiralty Islands where my husband and I had spent seven months in 1928. "Did you remember anyone?" they also asked, and I realized that either the questioners had never lived in a village themselves or they knew little about what anthropological field work was like. To the 210 people of Pere village, we were the kind of event that would be talked about again and again, and as long as I tried to think and write about anthropological problems, the memory of the people—especially the children, whom I studied intensively—would be sharp and clear in my mind, each small figure etched sharply against the background of the lagoon where their pile houses were silhouetted.

Once in a while, as I went back and forth to the South Pacific, and as members of other departments of The American Museum of Natural History went on their separate expeditions, I would receive some scrap of news. I heard that soon after we left—and they had beaten the death drums as our canoe pulled out of the village, for they were as sure as we were that we had left forever—a Catholic missionary had established himself in the village and had set up a school in our house, a house that lacked the good lines of the native structures because it had been built to let in more light. I once met a trader from Manus who told me reproachfully that several young men from Pere, who had been part of the children's group that had run my household and made thousands of drawings for my psychological study of child thought, had stolen a big canoe and sailed away to the nearest large island. His voice suggested that we had been a bad influence. But he had never stopped to think about how 14,000 people, speaking some twenty different languages, had originally reached that isolated archipelago, and that thousands of years ago somebody doing some long-distance sailing had most likely been blown off course.

Before glottochronology, a linguistic analysis that determines when a language diverged from a mother tongue, was developed, we had no way of estimating how long ago that trip took place, as no archeology had been done. We were, however, able to get a pretty good idea of the way the different language groups had specialized over the course of centuries of growing coconuts and taro on the big and small islands, trading sea products for land products along the shores, going on long voyages to hereditary trade friends to exchange a turtle or a freshly caught dugong for a large tree to be used as a housepost or a canoe. They filled shelves in the rafters of their big houses with pots and baskets made waterproof with gum (parinarium), spears with obsidian points, spider web lures, ladles and bailers carved by peoples who were both trade friends as individuals and enemies in sporadic warfare.

There was respect, contempt, envy, and hostility among the peoples of this small world—the only world they had known until European dis-

Margaret Mead with the children of Manus. From her first trip to the Admiralty Islands in 1928, top left, through a series of visits (1953, center left; 1964, bottom left, and 1975, right), Mead has particularly studied the growth of children as the area itself has evolved into a modern state.

Berbara Haath

Margaret Mead

Barbara Heath

John Kilepak (second from right, above) was one of five boys that lived in Margaret Mead's house in Manus during her 1928 trip. These boys ran the household (Kilepak was the cook) and provided data for her psychological study of child thought. Thirty-five years later, Kilepak, right, had become a local leader and, like many postwar Manus, had adopted Western dress. In 1969 he visited anthropologist Barbara Heath at her Carmel, California, home and spent six months demonstrating traditional woodcarving skills, lecturing, and visiting with her friends (page 63, top). Now about sixty years old, Kilepak is an important elder in Manus (page 63, bottom).

covery of Papua New Guinea. First the Germans and then, after World War I, the Australians had preempted the good, level land for coconut plantations. They imposed a rough sort of law and order and recruited young men to work on ships, on distant plantations, or as wharf laborers at the ports.

In 1928 the adventures of going away to work as an indentured laborer had replaced the adventures of warfare and the capture of women. Iron had replaced obsidian and stone in knives and adzes. Beads made in European factories had supplemented the beads made of shell that were used in trade; for payments for small services; for the great exchanges that surrounded and validated betrothals, marriages, births, and deaths; for redistributing valuable imports within the villages; and for keeping up the level of food production.

The system that kept men and women working unremittingly—to meet obligations that lasted through generations after each marriage was contracted—was stimulated by the addition of the new things brought by the Europeans. The traders paid in large packets of tiny beads for each packet of sago they took to feed the workers on plantations and the boat crews that joined the passenger ship that touched the port of Lorengau every six weeks or so.

As has happened in so many parts of the world, the first contact with the more complex technology and larger political system of the Europeans was stimulating. It improved the kind of fishhooks and tools people had to use; provided a wider occupational experience as boat crews, police, and child nurses; and offered new horizons for the future. They had already decided that some day soon they would become Christians. They would abandon the ancestral ghosts who hovered close to their preserved skulls, which hung in every house to discipline its occupants by making them sick and to protect them from the death-dealing malice of the ghosts of other households. Then they would learn to read and write and keep accounts to avoid the endless bickering over how many thousands of dogs' teeth and strands of shell money had changed hands and established indebtedness. European medicine was

still respected for curing ringworm, cuts, and wounds, but the "doctor boys," as the medical assistants who were set up in each village by the Australian Mandate were called, had little effect among a people who believed that all illness and misfortune were the result of sin, either sexual or economic. In their scheme of things, theft, failure to pay a debt, and even looking lustfully at a woman were equated.

Their view of their future and our view were as divergent as their clothes and utensils, their beliefs and ceremonies were from ours. They saw the world the Europeans were bringing as one of wider opportunities for trade and adventure, within which their own lives would go on essentially unchanged. The entrepreneurial men and their entrepreneurial wives would go on initiating marriages in terms of which the young, the dependent, and the unenterprising would work for them, while a few sturdy individualists would opt out of the complex and exacting exchange system and simply fish and trade at the local market to keep their families in food.

But we, as anthropologists, foresaw a different fate. We saw a culture that would become impoverished, as young men accustomed to foreign ways would come to despise the authority and ghostly sanctions of their elders. The people would be transformed into a kind of native proletariat, working at low wages for foreigners, losing what they had developed over thousands of years and gaining very little in return. They would become economically dependent, subject to capricious outside authority, when they had once been masters of the seas they sailed.

One of these authorities, insensitive to local marriage customs, had a few years earlier lined up all the unmarried people in the village and indiscriminately married them to each other. It took several years of argument to regularize those marriages: to find fictional links so that these marriage arrangements could be attributed to the proper pairs of contracting cross cousins, the children of a brother-sister pair. The children of these marriages, who were free of property considerations, would grow up and live in the "middle," half in the old system and half in the new, neither here nor there. They would be like our schoolboy linguistic assistant who was the only boy in the village who had been taken away to school—to perfunctorily fulfill the demands of the League of Nations in Geneva.

So when we left, we neither expected nor hoped to see them again. But twenty-five years later, in 1953, I went back, accompanied by two student apprentices, Theodore Schwartz and Lenora Shargo, to investigate the enormous and unexpected changes that the Second World War had brought. Manus had been a major American base; great barracks had been built, surgeons performed miracles of patching up the wounded, as big ships and planes came and went. After the war, Manus was swept by a cargo cult, whose leader prophesied that if the people would throw away all their possessions, the ghosts of their ancestors would bring them large supplies of European goods—airplanes, modern drugs, and tons of food.

But while most Papua New Guinea cargo cults had petered out as a result of government disapproval and disillusioned believers, this political movement had thrived among the Manus people. Led by a man named Paliau, they had rebelled against the mission and set up a miniature government of their own, complete with schools, hospitals, "customs," "passports," parliament, and their own version of Christianity, in which the Lord God, despairing of his European representatives, decided to try the people of New Guinea themselves. The transformation had been so astonishing that my Australian colleagues insisted that I, who had known what they had been and projected what they might become, had to go back and find out what was really happening.

This was a new experience in anthropology. True, field workers had often returned to the site of their original work to follow up old leads, and field workers had studied in places where previous field workers had gone, to quibble over small points or to look at the people through eyes informed by new theories. But no one had studied children as I had, and so, no one had been able to return to find them as adults in charge. The world

Barbara Heath

Fred Roll

Margaret Mead

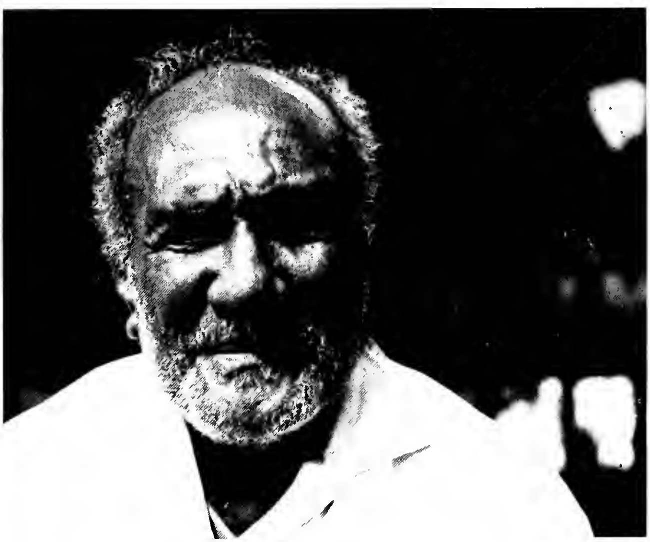
had never witnessed such rapid transformations from the end of the Stone Age to the Electronic Age, because there had never before been such vast technological gaps to traverse in so few years.

I found the people vigorously pursuing a course of modernization they felt to be their own—not imposed upon them—under a leader who was astute, imaginative, and farsighted. He had plans not only to eliminate the petty animosities of the Admiralty Islands but also to include the whole Bismarck Archipelago in a new federation of cooperation, modernization, and brotherhood. Like other recurrent Papua New Guinea responses to European political and religious ideas, it was to be a utopia constructed by adopting modern ideas—money instead of dogs' teeth, one God instead of ancestral ghosts and local place spirits, education instead of the trials of daring demanded by local warfare and headhunting, political unity instead of village feuds, and a rule of law instead of a rule of angry individual defense of rights and privileges. The European law—a law that would be substituted for feuds, supernatural curses, and sorcery, that would replace anger with good-humored friendliness—this was valued most.

A house was renovated for my use in their newly built land village, and my two young apprentices were set up in a nearby village. Again, I lived among the Manus for six months while recording the New Way. One of the reasons I had consented to go back, instead of exploring a new field as I had planned, was that I realized that the world was facing rapid social change, change in one generation instead of the more usual two- to three-generation shift from one way of life to another. We needed to know how this would work. In Manus I found perhaps the most successful model yet recorded. The Manus were practical, enterprising, interested in how things worked, willing to take chances with their children, confident of their own capacity to cope with new conditions. There was a good fit between the older system and the new, larger system into which they had no choice but to adjust.

It was possible to say that change such as had occurred there, in which

Theodore Schwartz



Theodore Schwartz

With his son Matawai alongside, Pokanau (page 64) plays traditional panpipes (1929). When Margaret Mead saw him again in 1953 he had become the authority on traditional law and was called the "lawyer man"; in that year he gave a speech at a new-style wedding ceremony, above. In 1964 he was an old man, left, who had outlived his strength. Pokanau died several years ago.


Reo Fortune


Fred Roll

Shell money and dogs' teeth were part of great family exchanges, such as this 1928 marriage dance, top. In 1975 a cash exchange, above, validated a marriage. Elements of the old and the new can be seen in the women's dress (page 67, top) in which Western-style brassieres are complemented by grass skirts. Wooden slit gongs (page 67, bottom) abandoned after the war for gongs made from torpedo cases, are once again part of celebrations, as are old dances, songs, and oratory.

a whole system was transformed, could release extraordinary amounts of energy. Old affinal exchange patterns, exploitative kinship patterns (in which young men slaved for their elders), and fear of illness as a principal sanction for good behavior were swept away in favor of the impetus provided by group achievement, cooperative action, and pride in mastering the institutions of the superordinate culture. It seemed that self-initiated, complete change was better and more efficient than piecemeal change in which people partly adjusted to partial change, as a man might limp on a sprained ankle, exacerbating the inflammation. From situations such as I had found in Manus in 1953, we could take new hope that the millions of people caught between the old and the new might make a smoother transition than we had expected.

When it came time to leave, they gave a big farewell feast for me the same night they received word that their new political system would have government recognition. This time the people bade me farewell with more depth of feeling, for now I had witnessed their successes, but again, neither they nor I expected we would meet again. "Like an old turtle, you are going out to sea to die," said old Pokanau, who was, he thought, older than I. Of course, nobody could be sure of this, for ages had only been kept since 1946, the year to which they trace their birth as a modern society.

In 1963 Theodore Schwartz decided he wanted to make an aerial survey of the twenty different language groups in the Admiralties, and so we organized a new three-year expedition. I went back three times to record still more change. The first new village had fallen apart; they had planned and built another one with a great open plaza into which a new government school had to be crowded. With the new school, all of their relatives and connections from a neighboring village moved in. Almost overnight the plagues of the modern world—crowding into cities, pollution from deposits of human waste in the sea, and juvenile delinquency—appeared, ten years out of the first proud modernization effort.

Paliau had built himself a large,

ugly modern house out of tin and was now a member of the new Papua New Guinea Parliament. But his political genius was beginning to be compromised by his lack of English, which the younger generation of Papua New Guineans was rapidly mastering. The first student from Pere had entered the new university, and young Manus men and women were entering the educated sector in large numbers as teachers, nurses, clerks, interpreters, and accountants. Younger men were trying to take over from the Old Guard who had made the original successful social revolution and who thought everything should remain just as they had made it.

The people had still not realized much economic progress because the island has few resources. They were investing all their hopes in their children, gladly sending girls as well as boys to the school in Lorengau, and then on to higher education. Their version of Christianity was wearing a little thin with repetition without new vision. But Paliau had politically integrated the whole of the Admiralties so that in 1965 at Christmastime, which had traditionally been the political gathering point during the formation of the new society, people from all over the archipelago came to Pere. It was hard to get much anthropological work done that year because people were out in the bush working sago from dawn to dusk and everybody went to bed exhausted in the early evening, saving themselves and the fuel for their lamps for the big event.

The next year National Educational Television sent out a team to make a film of this small, vigorous society that had so blithely deserted the old ways for the new. The film ended with another "final farewell." These farewells were like Manus deathbed scenes: people gather around illness because they have no way of knowing whether or not someone who is sick will die. There was no way of predicting whether or not I would ever be able to come back.

But in 1971 I went back again with my colleague Barbara Heath, a physical anthropologist who had been following the entire population as children grew and the mature aged, showing us how odd traits, such as one blue eye, repeat themselves in the


Barbara Heath


Barbara Heath


Theodore Schwartz


Barbara Heath

third and fourth generation. Things in Manus had taken another turn, as the people again condensed into a few years the learning that has taken other societies decades or even centuries. They were dissatisfied with schools; half their children were left in the village after finishing school, too small to work, too young to marry, with no place in society and no way of obtaining even pocket money, while their slightly more scholarly brothers and sisters had gone away for further schooling. With their usual energetic way of tackling problems, the parents discussed what was to be done, struggling with the old idea that the children's labor belonged completely to the parents until they could work their way free.

The dream of modernization was failing a little, and now, like people all over Papua New Guinea, they were beginning to ponder what was worth saving from the past before it was gone forever. The slit gongs, once abandoned for a gong made from a torpedo case, were back. Paliau had built himself a new house, beautifully constructed of thatch and bamboo. He hadn't even used a level—"just my eye, to teach the people," he said. The old dancers were back also, in old costumes worn over modern dress, which looked unesthetic to our eyes, but not to theirs. Paliau agreed that once the old exploitative economic order was gone, the "pleasures" of the past—dance, song, oratory, and costume—became acceptable. These changes echoed events in the wider world, as young people everywhere were beginning to turn from pollution and energy waste to the traditional pleasures of the outdoors and activities that neither pollute nor waste, where the imagination is neither sated nor deadened.

Last summer, 1975, we went back again, in overlapping visits—first Ted Schwartz, then Barbara Heath, then I. I stopped first in Port Moresby, the capital of Papua New Guinea, a new nation that attained independence in September 1975. A north coast Manus man was now the chancellor of the University of Papua New Guinea. There, I spoke to excited students who argued the pros and cons of the accounts that I, as an anthropologist, had written of one of their more than 600 different language

groups, complaining that the customs of their own people had been different. I had a long talk with the son of Paliau's principal lieutenant, now minister of housing for the country. At a dinner party I met a young university instructor who came from one of the remote inland villages and was just leaving for the United States for a course in comparative literature. Twenty-five years before, it was the coastal and island people who had taken the lead in higher education, but now young men and women from all over Manus were responding to the high standards that had been set.

I heard that a daughter of one of the inland leaders was now a special adviser to the chief minister, and that she was in Manus helping to draft a regional contribution to the new constitution. When I reached Lorengau, the capital of Manus, I met her and we had long talks about the constitutional problems with which she was wrestling. The plans of the constitutional commission called for the establishment of electoral districts of equal size, which would have meant that villages that had been enemies for decades and possibly centuries would have had to choose a single representative. As an anthropologist who had studied Manus for almost half a century, I knew just what complications this plan would create. (Perhaps fortunately, this attempt to regionalize was abandoned at the last minute as politically inexpedient and too expensive.)

In Lorengau I also met the first young Manus poet who, after having traveled in Europe with the Moral Rearmament Movement for several years, was now teaching creative writing in the Lorengau high school. I met a theological student who returned to find a very poor reception for the brand of sophisticated theology he had learned at a seminary in Chicago. So he turned his energies to solving the problem of a polluted channel. He had persuaded his village to question the custom of allowing canoes from many villages to pass through the channel since the boats were now equipped with outboard motors going at full speed.

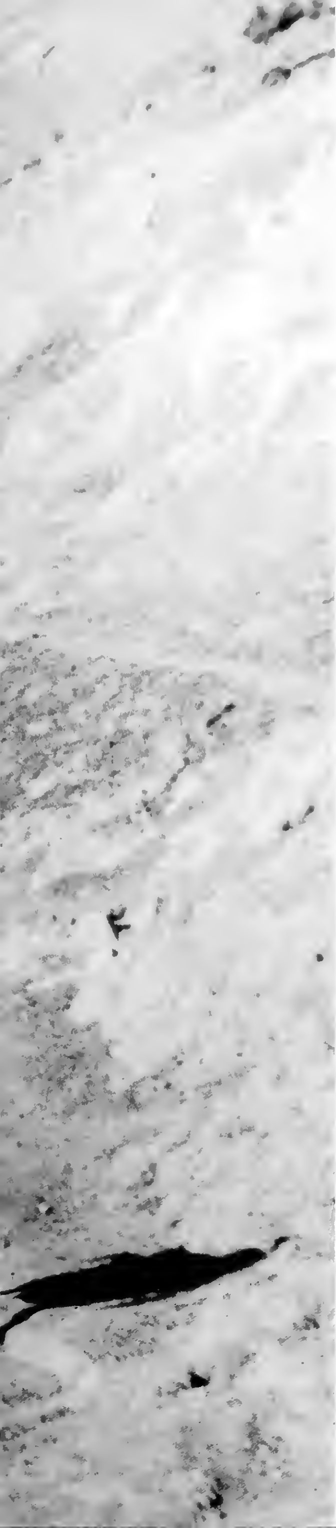
In the village my house had been renovated during our two-year absence. People had taken some of the floor boards out to reinforce their own floors, but now brought them back. The partitions had been improved by pieces of plywood taken from our friends' own houses, and the thatch had been mended. The village was seething with activity surrounding the preparations being made for two large exchanges. These exchanges restored some elements of the old style of validating marriages through the "side of the man" and the "side of the woman." The social transformation of 1946 had replaced this form with a new one called a "play," in which gambling winnings and European goods changed hands between principals who entered into these exchanges for pleasure. This differed from the traditional exchanges, which kept people working hard to provide the consumable parts of the exchange—sago, fish, pigs, and oil. But in the exchanges we saw last summer, the production of local food again played an important functional part, keeping the people busy producing food to meet their obligations.

Old Manus customs were also reappearing in a new set of sanctions placed on the young men by their elders. When the young men went away to work, the elders threatened them with curses if they failed to send remittances home, but the young also insisted that those elders should not dissipate the money; rather, they should put it to good use as investments for the younger men. And while the drop-out young boys were now away visiting their brothers and sisters in different parts of the country, some of the educated young men had returned to the village and were keeping records, making the local council more sophisticated, and resuming their hereditary occupations of fishing and trading.

The extreme emphasis on modernization and rejection of the characteristics of an earlier period were now gone. The society was still distinctively Manus, but with a new sense of identity, ready to combine the old and the new. I realized how little we had been able to learn when we used to study a people only once, and how illuminating and unique was this opportunity to follow the same population—a microcosm of the world—for forty-seven years, as they fanned out into the wider world, but retained the core of their culture at home. □

Fred Roll

The first village school (page 68, top) was in the church and was taught by a man with limited education (he had only reached short division). Today, a new school with modern desks (page 68, bottom) has four trained teachers and prepares children for further education at the Lorengau high school and Papua New Guinea University. When the first government school was built in the village, relatives from neighboring towns moved in and problems of the modern world—overcrowding, pollution and juvenile delinquency—became apparent. The child shown above is a member of the fourth generation Margaret Mead has studied.



Wild Goats of Santa Catalina

by Bruce E. Coblentz

Setting free this herbivore with the "destructive nibble" created a landscape of barren hillsides

Before the advent of refrigeration, nutritional diseases were common among sailors, many of whom lacked fresh fruits, vegetables, and meats during long ocean voyages. In the hope of at least partially overcoming nutritional deficiencies, ships sailing into remote seas often carried cargoes of domestic goats, not only to be eaten as part of a ship's provisions but to be liberated on virtually every oceanic island that was visited. These introductions were for the express purpose of allowing the goats to multiply, thus providing a source of fresh meat for future seafarers.

This concern with fresh meat was the primary reason for the spread of the domestic goat across the oceans. Surely many a malnourished sailor profusely thanked both his Maker and his anonymous seafaring benefactors when, having put in to shore on an uninhabited island, he found an abundance of goats for the taking.

Goat liberations were eminently successful wherever the animals were allowed to range freely and reproduce in the absence of large predators. Although basically a grazing animal of dry uplands, the domestic goat was adaptable to a wide range of climates and vegetation types. As a result of early goat introductions, many oceanic islands—most notably New Zealand, the Hawaiian Islands, the Galápagos Islands, many islands off the Pacific coast of Baja California, and the Channel Islands off the coast of southern California—have high populations of these remarkable animals.

In a few cases the precise history of goat introductions is known. Captain Cook was responsible for introducing goats to New Zealand in 1773 and to Hawaii in 1778, where they were originally cared for royally by the native population.

On other islands, however, the origin of goats is uncertain. Santa Catalina Island (or Catalina Island), in the Channel Islands group, has had goats since at least 1827, when the earliest known mention of them was made. Since they were already established by that date, we can assume that they were introduced well before then. Popular theories about the origin of Catalina Island's goats attribute their introduction either to early Spanish explorers, such as Juan Cabrillo and Sebastian Vizcaíno, or English pirates who later used Catalina Island as a base from which to carry out raids against the Spaniards.

More recently, another aspect of the introduction of goats to the Channel Islands has come to the fore, and its importance does not lie in who liberated the goats, but in why they were liberated. In the early nineteenth century, conditions on board ships were so poor, as was treatment of the sailors, that a ship stood to lose part of its crew if it approached a mainland port. Thus, the thinking is that the goats were liberated on these islands

Traveling in customary single file, a bachelor herd of feral goats heads for a nightly bedding ground within its home range on Santa Catalina Island.

Bruce E. Coblentz

Bruce E. Coblentz

One-week-old kids in a nursery herd peer over a ridgetop. The nutritional status of adult males seems to control the onset of four annual breeding periods.

so that ships could take on a supply of meat without having to put into a mainland harbor.

At present, however, the need to remove or control goats takes priority over speculation on their origins. On most islands the goat population has already caused serious damage to native plant and animal life.

For a 22-month period from July 1971 to May 1973, I studied feral goats on Catalina Island with a twofold purpose: to learn more of their social behavior and to study their ecological effects upon the island. Catalina Island lies about twenty-five miles offshore from Los Angeles. In spite of its proximity to this densely populated area of the West Coast, the island has only about 2,000 year-round residents, and the overwhelming majority of these live within about one square mile in the town of Avalon. Most of the island's remaining seventy-four square miles consists of undeveloped brushy ridges and canyons with a few small grassland areas in the interior. The rugged topography and semiarid climate make Catalina an ideal habitat for goats.

I soon found Catalina Island goats existed in discrete herds, or populations, with nonoverlapping home ranges of one to two square miles. These home ranges were usually bounded by a zone perhaps fifty yards wide on a ridgetop or canyon bottom. Fences became abrupt boundaries, as did paved roads.

The nearly 200 goats in the study area were readily distinguishable by natural variations in coat color and pattern, age, sex, and horn shape. These individual goats had a high degree of fidelity to their own herd home range. The rare observations of goats outside of their home range were almost always of males of adjacent herds during the short breeding periods.

As expected, I found Catalina goats breed like other members of the Caprinae, a subfamily that includes all of the goats and sheep, the chamois, and serows. Large, dominant breeding males guard single estrous females from less dominant males. Once a male successfully breeds a female, he then guards her from other males for a short period after copulation, presumably to insure fertilization by his sperm; then begins seeking other receptive females. As a general rule, females only accept one male, but males breed as many females as they are able. Although this is a polygynous breeding system, serial monogamy is probably a more descriptive term.

Unexpectedly, each discrete goat population on Catalina has four rather regularly spaced breeding periods per year, which I have termed a quadrimodal breeding system. This system, apparently unique among ungulates, appears to be controlled by the nutritional status of the males. After mating with numerous females, the energy level of the male is relatively depleted. A period of feeding is necessary before his physical condition peaks again, enabling him to resume breeding.

Males seem to be able to induce synchronous estrus among any females in the population that are in sufficiently good health to be in reproductive condition. The males do this by producing pheromones, chemical secretions that produce a response in other individuals. These pheromones are presumably released through the males' urine. By directing this pheromone-containing urine into the long hair of the anterior half of their bodies, the males, in effect, become billboards of reproductive inducement. Dominant males exhibit greatly increased frequency of this urine-marking when they are in peak physical condition, the point at which they have a better chance to breed a maximum number of females. Fe-

Overbrowsing by goats has caused severe ecological damage. A fence erected to exclude goats from the central portion of the island has enabled plant life to regenerate.

Bruce E. Coblentz

males, in turn, begin coming into estrus two to three weeks after the onset of the greatly increased rate of scent urination in males. It is obviously of selective advantage for a male to be able to cause females to come into synchronous estrus when the male himself is in peak physical condition.

Nutritional control has yet to be demonstrated through experimentation, but it is suggested by the lack of breeding period synchrony between populations across Catalina Island.

Before a male in peak condition can gain access to receptive females, however, he must either have already established high dominance status with the other males in the population or he must be physically able to do so when challenged. Usually, unresolved dominance status between two male goats is determined through various kinds of threat behaviors, with the smaller of the two declining to fight. Only when both potential combatants are fairly equal in size might an actual fight develop.

In fighting, males make contact with their horns. The two basic techniques are as follows: (1) one of the males rears up on his hind legs and delivers a hard downward blow to the braced opponent and (2) males align in parallel fashion facing the same direction and interlock horns so that the strong neck muscles can be used to try to overpower the opponent's neck muscles. In rearing and clashing, the goat that is up on his hind legs always circles his opponent first and stops on the uphill side. By delivering the blow from the uphill side, considerably more force can be generated.

Once a male wins the right to gain access to females, the most difficult and risky aspect of reproduction is past. In general, if the male is a dominant individual and the female is in a receptive state, she will quickly accept the male and permit copulation.

When initially approaching a female, the male performs a series of preliminary courting gestures. These appear to accustom the female to physical contact and simultaneously test her sexual readiness. A female signifies her acceptance of a courting male by rubbing his neck with her horns. At this point the male abandons his preliminary courting gestures and initiates intensive courtship behaviors. These lead to mounting and, eventually, copulation. If the female does not signify acceptance of the male, the male will not perform intensive courtship patterns and may attempt mounting as a direct transition from preliminary courtship. Such attempts at "rape" are invariably unsuccessful.

Within each herd home range there is one primary and one or more secondary bedding grounds. These are traditional areas to which goats return in the evening to spend the night. Major bedding grounds are characteristically situated so that in one direction there is a precipitous escape route, leading away from the bedding ground, while in the opposite direction there is easy access, generally along a fairly level ridge.

In the morning, goats always leave the bedding grounds in large associations, then break up into smaller groups for the remainder of the day. Daily activity consists of a feeding loop pattern through a part of or, on occasion, the entire herd home range. The predictability of both the times and the places of the goats' activities made observations relatively easy.

By being virtually tied to a particular area, goats will essentially bring themselves to the brink of starvation without leaving the familiar area that provides them with a sense of security, even when areas of better forage are nearby. Certain herd home ranges on Catalina are in particularly bad condition due to this characteristic.

In the past, goats seemed to be an asset in making use of "worthless," uninhabited islands; today they are viewed as a destructive ecological force that requires control or total elimination. Wherever they have been introduced, goats have severely damaged the native vegetation; in some cases they have driven particular plant species to extinction. This is especially true in insular ecosystems where the vegetation has generally evolved through long periods in the absence of large herbivorous animals. These endemic insular plants have generally evolved few physical or chemical defenses against browsing by herbivores.

It is known that goats have exterminated several species of plants in the Galápagos, and many of the forty-eight indigenous plant species that have disappeared from Catalina Island were probably eliminated, wholly or at least partially, because of the presence of goats. Certain other species exist on Catalina today only because the few surviving individuals grow where it is physically impossible for goats to reach them.

Only in recent years have researchers begun to document the damage that goats have done to native vegetation of goat-afflicted islands.

In Hawaii Volcanoes National Park, a series of exclosures were constructed in areas of high goat populations to determine the response of the vegetation to protection from goats. To everyone's surprise, a previously undescribed plant species began growing almost immediately from seeds that had lain dormant in the soil. We may postulate from this discovery that the seeds of some other plant species believed eaten to extinction by goats may also be lying dormant in the soil, waiting for the goats to be removed before they can begin to grow.

The danger of uncontrolled herds of goats goes beyond the mere alteration and suppression of plant species or communities. Continual overutilization and trampling by goats leads to severe erosion, which in a semiarid Mediterranean climate like that of Catalina Island, rapidly removes virtually all of the thin soil cover. Once the soil has been lost, hundreds of years may pass before the habitat recovers naturally. The goat has been blamed for contributing to the current lack of forested lands in the Mediterranean region and, in turn, possibly to the semiarid climate that has come about with deforestation.

In addition to their direct damage to the vegetation and soil cover in an area, goats also have a substantial effect on other animal species. Because goats reduce both food and cover, an-

A wild goat on San Salvador Island in the Galápagos. As on the Channel and other oceanic islands, seafarers released goats to provide a future source of fresh meat.

N. Devore III; Bruce Coleman, Inc.

imals that require dense ground cover or abundant ground level food—such as small terrestrial rodents, reptiles, and ground-nesting or ground-feeding birds—may be excluded rather quickly. The over-all effect of plant overutilization, erosion, and compaction also contributes to increased mortality of trees and to the reduction of forested areas. This, in turn, tends to eliminate any animal species dependent upon the forest habitat. As time goes on, the goats create a habitat that is exceedingly inhospitable for most other animal species.

In less than 200 years in Hawaii, the goats have been described as having "chewed their way from the seashore to the tops of island peaks and back down again." On Catalina Island, goats have not only worked their way from the seashore to the mountain peaks and back down again, but some herds travel from the peaks to the shore on an almost daily basis. In their daily travels they make use of any suitable terrestrial vegetation encountered, and on occasion they graze on kelp and other marine algae found in the intertidal zone.

This "destructive nibble" of the goat is also directed at forage of poorer quality than that utilized by almost any other herbivore. Bitter, oily plants may be taken, almost exclusively, by goats. The problem is that goats, like any other herbivore, will take all of the higher quality food first and only then turn to the lower quality food. Before the forage in an area is all of poor quality, the goats will have removed the forage of sufficiently high quality to sustain other herbivores. This usually insures that the goats will be the only large herbivores in an area where they are allowed to increase unchecked for extended periods.

On Catalina, mule deer were excluded from areas of high goat density owing to the lack of food. Deer were regularly seen in adjacent goat-free areas, but not in the goat ranges themselves. Feral pigs were found in both goat and goat-free areas; however, the pigs in goat areas were generally smaller and appeared to be in much poorer health than those found elsewhere on the island. Likewise, litter sizes of pigs were smaller in the goat areas. One reason for their ability to live in the goat areas was that the pigs physically outcompete the goats for certain seasonally limited, high-quality food sources such as acorns and other fruits.

The effects that the goats have had upon certain passerine birds on Catalina is not certain, but on Guadalupe Island to the south, they have definitely brought about the elimination of at least three species. On Catalina, the endemic subspecies of California quail, a ground-nesting and ground-feeding species, is obviously less abundant in, or absent from, areas of high goat density, as are three of the five endemic terrestrial mammals: the island gray fox, the deer mouse, and the western harvest mouse. Only the ground squirrel seems to do well in goat-disturbed areas. (The status of the fifth endemic species, the Catalina shrew, is unknown.)

Not only do goats denude the areas in which they live, but because of their tendency to travel between areas in single file, they establish many distinct goat trails throughout their home range. This concentrated trampling, and resultant soil compaction, removes a considerable amount of goat habitat from production and thereby reduces the over-all productivity of the area. In most areas where goats have become established, they travel along distinct, well-worn, and often traditional trails. The constant use of these trails has made the surfaces nearly as hard as concrete. On frequently used trails nothing grows at all, while on occasionally used trails the little that does manage to begin growing is soon trampled and killed, if not eaten first.

On a single hillside there can be many trails, although one or two always stand out as those most frequently used. The combined area of all the trails on a hillside can be considerable, perhaps as much as 2 to 3 percent of the area. Goat trails generally follow the easiest route between two points and generally parallel a hillside, although in a few places trails do run in a more uphill–downhill direction. In many such places the trails have initiated significant gully formation.

By causing severe erosion and runoff in an island situation, goats may also adversely affect the littoral marine environment. In the absence of plant cover, soil is rapidly washed down to the ocean where it can settle out and perhaps choke the sessile filter-feeding organisms that are present. After winter rains, ocean areas near certain canyon mouths on Catalina have been observed to be stained brown from the soil washed from the land. The amount of particulate matter in the runoff of these canyons appears to vary directly with the populations of goats in the particular canyon drainages.

The goat is perfectly designed for utilizing the quantity and quality of vegetation that it does. Like most ungulates, goats are ruminants, meaning that they have a four-chambered stomach, the forechamber being the rumen. The rumen is greatly enlarged and acts to facilitate bacterial and protozoan fermentation. Lacking the enzymes required to break down cellulose and other relatively impervious, energy-containing carbohydrates, the ruminants depend upon the vast numbers of bacteria and protozoans in the rumen to break down these compounds for them. These microorganisms digest much of the plant material that the animal eats and produce volatile fatty acids as a by-product of fermentation. The metabolites that result from the microorganisms' digestion of plant material are absorbed directly from the rumen and provide energy, as do sugars in simple-stomached (monogastric) animals. The microorganisms themselves are then digested as they pass into the animal's intestine.

The advantage of the rumen lies in the fact that foods of relatively low quality can be ingested and utilized by the ruminant, whereas the same foods might result in starvation for monogastric animals. There is an inverse relationship between the relative size of a species' rumen and the diet quality that the species requires for maintenance. In general, the narrower the ratio of rumen volume to total body volume, the coarser (less protein, lower digestibility) the diet that the species can live on. All members of the Caprinae have a narrow ratio, but that of the domestic goat is especially narrow due to its relatively immense rumen. Because of this digestive anatomy, the goat can live on forage of insufficient quality to sustain other herbivores. Almost as important is the goat's extremely high

threshold for bitter and oily plants, which most other herbivores will avoid.

Owing to the goat's unique combination of abilities to utilize food, there is essentially no plant species that is 100 percent safe from utilization. No plant species—not even tree tobacco, prickly-pear cactus, and the poisonous locoweed, which were found growing in the goat areas of Catalina Island—was completely free from utilization.

In addition to this digestive capability, the goat is behaviorally adapted to procure food in situations that would thwart all but the most highly specialized herbivores. The goat is exceedingly surefooted; it can reach vegetation growing on nearly vertical cliffs and canyon walls and climb trees whenever there are low horizontal limbs or inclined trunks. On Catalina, it was not unusual to see goats moving from limb to limb searching for forage in scrub oaks or other trees.

Even in normal, everyday feeding, goats frequently stand upright on their hind legs and use their front legs to push vegetation down. They can literally walk an upright stem down to the ground and eat the foliage off the top while standing on it. When finished, the goat steps sideways and a considerably denuded stem springs back to an upright position.

Goats are also individually adaptable, as evidenced by the varied methods used to render a prickly pear less painful before it is eaten. Some goats simply paw at the spines to break them off, while others break the pad off and then hold it in the mouth while rubbing the spines off on the ground. Some goats butt the cactus to a pulp with their horns and then take bites out of the crushed plant; others take bites out of the undamaged pads. All goats eat prickly pears and, in fact, go to great difficulty to obtain them, probably because these "cactus apples" are particularly palatable. As a general rule, in areas of high goat populations only those plants that are too straight or large to climb, or that grow in the protection of a formidable patch of prickly pear, are completely free from utilization by goats.

The primary problem in controlling feral goat populations is that, in most cases, absolute elimination is the only viable, long-term solution. Based on data collected from feral goat studies in New Zealand, it has been conservatively estimated that if a population of goats is reduced by 80 percent, it can recover to 90 percent of the original number in just four years. This means that if the population to be removed is not completely eliminated, subsequent control will be necessary at frequent intervals. In addition, the New Zealand calculations were based on the assumption of a fixed rate of reproduction. In actuality, we know that reproductive rate increases as population density decreases, so that as goats are removed, the reproductive rate of the remaining goats will increase and the original population level will probably be reached sooner than predicted.

In contrast to the reproductive rate of the New Zealand goats, and the even higher possible rate of increase of domestic goats, Catalina goats have a poor reproductive rate due, basically, to the poor nutritional level of goats in areas of high density. Well-fed domestic goats may give birth to twins or occasionally triplets every eight or nine months. In contrast, Catalina goats average less than one birth per year (actually less than one per 16 months) and only about 1.2 young per birth, considerably less than biologically possible for the species. Interestingly, recent evidence on Catalina indicates that due to a series of excellent growing seasons the rate of reproduction is noticeably increasing.

Although goats are easily found and removed at first, the greatest stumbling block to complete goat removal is that the amount of time and effort required per goat increases greatly as the population density decreases—a sort of diminishing return on effort invested phenomenon.

When a goat control program was instituted on Catalina about fifteen years ago, an attempt was made to totally remove goats from certain geographically defined portions of the island. This objective met with success in a large central portion of the island where there are currently no goats. The numbers of plant species and individuals present and the total production of native vegetation have recovered to a remarkable degree in this goat-free area. In other areas of the island that did not lend themselves to complete elimination as easily, small remnant populations have required frequent follow-up removal operations to allow the vegetation to continue recovering.

The contrast between goat-free areas and areas of high goat density is now considerable in all seasons, in terms of the flora and the fauna present. Not only is the density of vegetation greater in the goat-free areas, but due to increased organic litter buildup and greater moisture retention of the soil, the size and growth rate of individual plants is also much greater. Whereas in the goat area wild oats may reach a height of only a foot before setting seed, in the goat-free area the same species will reach three to four feet. In addition, some species, such as California sagebrush, Saint Catherine's lace, and the perennial bunch grasses that were eliminated or severely depleted in the goat areas long ago, have reestablished themselves in many of the goat-free areas.

Ironically, the goat has become an ecological liability because of the very qualities that made it an asset and a friend of man for the past several thousand years. The utility of the goat has been threefold: (1) Its fairly small size and low enough value have allowed it to be owned even by poor people. (2) It can survive on forage of extremely poor quality, such as that found in harsh arid environments or in other areas during severe drought. (3) It has a potentially high rate of reproduction. Perhaps even more importantly, the goat has proved adaptable enough to survive and reproduce in the humid tropics, a feat that few temperate zone ungulates could accomplish.

Obviously, an animal adapted to survive in such a wide range of environmental conditions, and whose adaptability has been rewarded through selection of the best-adapted individuals, could be expected to overtax virtually any environment into which it was liberated with no constraints placed upon it other than food limitation. In the past several thousand years man has been creating and perfecting this ecological monster; now man must impose controls where natural means have failed. ☐

Roses Are Red, White, Yellow, Pink . . .

by Patricia W. Spencer

The colors of plants, long a source of poetic inspiration, also help assure next year's fruits and flowers

Deflating though it may be to a human view of things, the flowers that bloom in the spring do so for their own reasons. While winter-weary souls may be heartened by the bright yellow of the first crocus pushing through the ground, that bright color is also vital to the plant's functioning. The plant world abounds in color. Whether in its flowers, fruit, leaves, or roots, somewhere along its evolutionary pathway almost every plant has developed the coloration that brings it to mind—rose, carrot, lemon, spinach, blueberry, grape—the colors of the rainbow from red to violet.

An aerial rainbow is formed from sunlight in much the same way that "white" sunlight is broken down into its colors by passage through a prism. A beam of white sunlight is composed of red, orange, yellow, green, blue, and violet light, with infrared above the visible red and ultraviolet below the visible violet. The same sunlight that gives rise to the aerial rainbow produces the rainbow of colors in the plant world.

Almost all plant coloring is produced by three types of organic pigments—anthocyanins, carotenoids, and chlorophylls—which are manufactured in plant tissues. That these pigments produce color at all is the result of their interaction with sunlight.

Sunlight is energy. When a beam of sunlight encounters a pigment molecule, such as chlorophyll, some of the sun's energy is captured, or absorbed, by the molecule. Chlorophyll appears green because it captures the energy of red, yellow, violet, and some blue light. The remaining light is reflected from the molecule, and since this is mainly green, we see chlorophyll as green. The other two pigments behave similarly with regard to light, absorbing the energy of some colors and reflecting the rest.

Unlike the aerial rainbow, in which each color band occupies an equal portion, the rainbow in the garden is overwhelmingly green. The most abundant and important pigment, chlorophyll, reflects this central color back to us. But a great variety of green is produced by this one pigment: celery, lime, olive, avocado, leaf, moss, fig, and fern are but a few names that bring to mind a particular shade or hue of green.

The quantity of chlorophyll present in the tissue determines the intensity, or shade, of green in a leaf or stem. Thus, Swiss chard and spinach contain far more chlorophyll than lettuce or celery. For the same reason, a small, newly expanding leaf is a paler green than a fully mature one. The hue of green, however, is determined by the presence of the other two major pigments. A large amount of the yellowish pigment carotenoid present with a moderate amount of chlorophyll produces a yellow-green, as in a lime. A deep, almost black-green results from a large quantity of the reddish pigment anthocyanin, as in the leaf of a red maple.

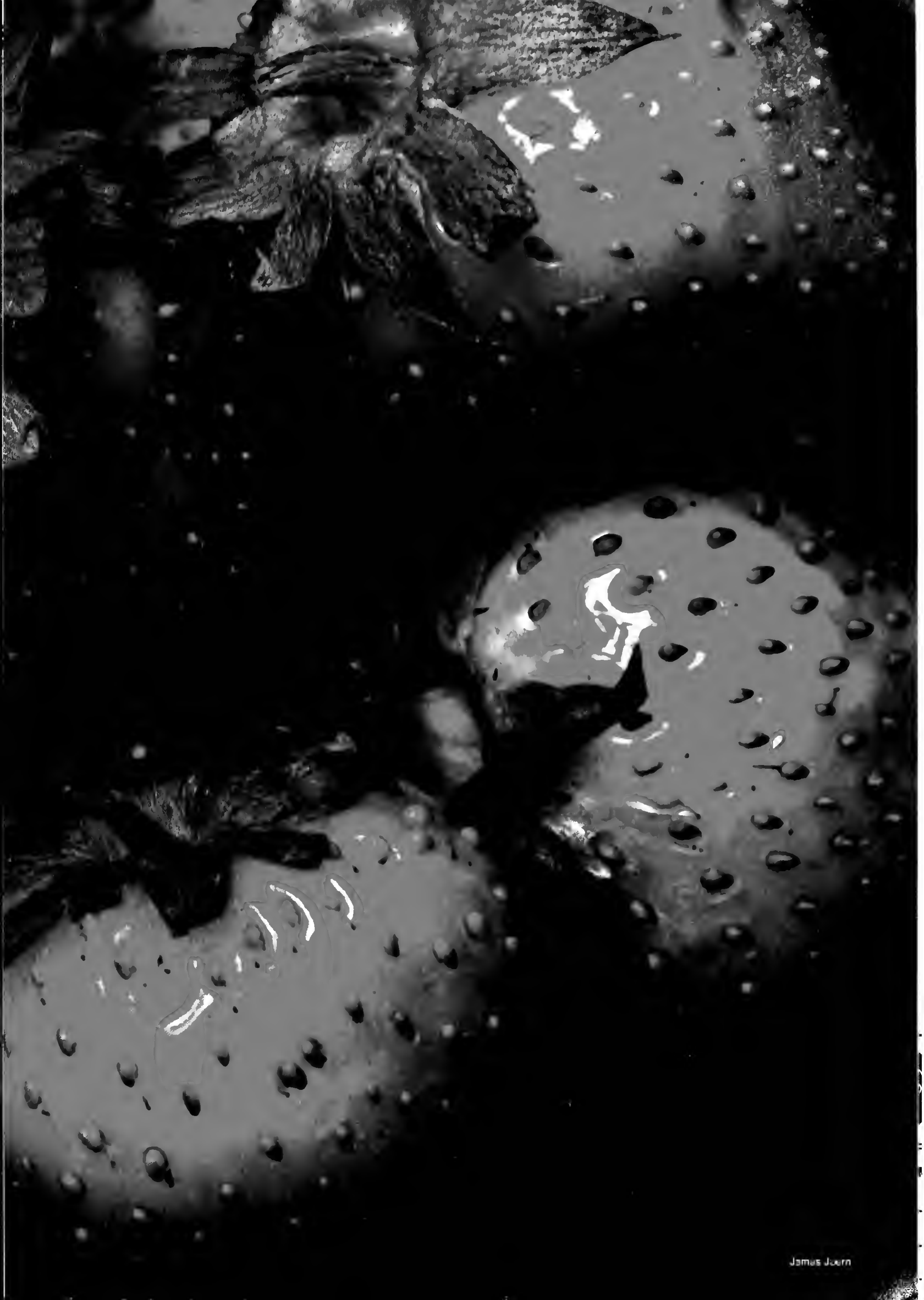
Regardless of its shade, chlorophyll performs one vital function in the plant world: in the process of photosynthesis, chlorophyll converts the light energy it has captured into chemical energy. The plant uses the captured light energy to produce simple sugars from carbon dioxide and water. Since all green plants depend upon this production of sugars as their sole source of carbohydrates for growth and development, nearly all aerial plant parts contain some chlorophyll or the ability to make chlorophyll. What is but one color in the aerial rainbow is the reflection of the very life of a plant.

Above green in the rainbow is yellow and then orange. The second most abundant and important pigment in nature, carotenoid, reflects these two colors in the plant world. Carotenoids absorb the energy of violet, blue, and some green light, reflecting yellow and orange light. Two slightly different forms of carotenoid are common in plants. One, beta-carotene (from which the vitamin A of carrots and other vegetables derives), is responsible for the orange color of carrots, sweet potatoes, pumpkins, oranges, and many other similarly colored fruits and flowers. The other major form of carotenoid, xanthophyll, gives yellow to such fruits and flowers as lemons, golden delicious apples, corn, grapefruit, some tomatoes, buttercups, chrysanthemums, and so on. (A minor form of carotenoid, lycopene, contributes a bright orange-red to such fruits as tomatoes and red peppers. The chemical structure of this molecule is

A handful of plant pigments produce a myriad of colors, from the yellow of melons to the red and green of peppers. Chlorophyll, the most abundant and vital pigment, is present in all plants.

James Joern

Thomas D. W. Friedmann, Photo Researchers


James Joern

James Joern

Anthocyanin, the pigment that produces the red of strawberries (pages 80-81), is also responsible for the purple of grapes, left. Plant geneticists, selecting for taste and growing and shipping qualities, also strive for pleasing color.

slightly different from either carotene or xanthophyll and thus interacts with sunlight slightly differently to reflect more red light.)

In many flowers, mixtures of carotene and xanthophyll in varying proportions produce a range of colors from lemon-yellow to deep-orange. The more carotene and the less xanthophyll, the more orange colored is the flower; conversely, the less carotene and the more xanthophyll, the more yellow the flower. Although most yellow or orange flowers are colored by carotenoids, a few, such as snapdragons, are colored by a plant pigment called an aurone, which has a very limited occurrence. To detect aurones in a yellow flower, you can expose the blossom to the alkaline fumes of ammonia or the vapor of a lighted cigarette, which makes it turn orange.

Almost all plant leaves and stems contain carotenoids, often in high enough amounts to alter the over-all color to yellow-green. Sometimes their presence is not apparent until autumn, when tree leaves begin to lose their chlorophyll and the carotenoids are unmasked, spilling into sight with brilliant yellows and oranges.

By funneling the light energy they capture to chlorophyll molecules, carotenoids play a secondary role in photosynthesis. Although the transfer is somewhat inefficient, they do provide some energy. Perhaps more importantly, carotenoids confer protection to plant tissue. Just as pigment cells in human skin darken (produce suntan) and protect underlying tissue, carotenoids, by absorbing and dissipating ultraviolet rays, prevent damage to plant tissue.

The quantity of chlorophyll in its tissues determines a leaf's shade of green. For this reason, a small, growing leaf is paler green than a fully mature one.

The remaining major pigment, anthocyanin, colors all the brilliant reds, pale pinks, sky blues, and deep purples—colors that contrast most with the overwhelming greenness of the plant world. Although anthocyanins are not as abundant as chlorophyll and carotenoids, this pigment type is the most widespread and important pigment in fruits and flowers. Anthocyanins color 90 percent of all reddish leaves, 85 percent of all fruits, and 70 percent of all flowers. That this one pigment is responsible for both ends of the rainbow—red and purple—with many combinations of color in between, attests to a natural parsimony.

The red rose, pink hyacinth, violet pansy, blueberry, strawberry, apple, plum, grape, and raspberry are but a few of the different colors reflected by anthocyanins. Since the colors produced by anthocyanins are mixtures of red, blue, and violet light, they offer many more shades and hues than the aerial rainbow. The naming of each color becomes subjective: what I call red, you may call rose; what I call purple, you may call plum.

This variety of color is achieved by several ingenious means. Anthocyanin, for example, like litmus, is a natural pH indicator. (Litmus is an organic plant pigment obtained from various species of lichens.) In acid, anthocyanin is red, while in alkaline, it is blue. This can be demonstrated in flowers containing some form of anthocyanin: a red dahlia exposed to the alkaline fumes of ammonia will become bluish, while a cornflower exposed to fumes of vinegar or another acid will become reddish.

Since almost all plant tissues are normally acidic, however, anthocyanin would be reddish rather than blue if there were not other ways blue could be achieved. In some cases, a slight shift toward alkalinity, even though still acidic over-all, is sufficient to impart a blueing effect on the over-all color of anthocyanin present in a plant tissue. But in nature this is a minor cause for blue color.

Anthocyanins can also appear blue by the binding of metal ions to the anthocyanin molecule, which changes the way it interacts with light. Such anthocyanin molecules produce the blue color of blueberries and many blue flowers, such as cornflowers. In a similar manner, when some minor pigments bind to an anthocyanin molecule, the color reflected by the altered anthocyanin molecule appears more blue.

The most important means by which this pigment can appear so varied in color, however, is by subtle changes in its molecule. Whereas there are two major forms of carotenoid (carotene and xanthophyll), four major forms of anthocyanin exist. The anthocyanin molecule, a large, complex one, can be subtly altered without changing its basic shape. The addition of an oxygen atom here or the removal of a hydrogen atom there is sufficient to change the way in which the molecule interacts with light, thus changing the over-all color it reflects.

The four major forms of anthocyanin are cyanidin, pelargonidin, delphinidin, and malvidin (for simplicity, they are abbreviated here as cyan, pelar, delph, and malvid). Each one commands a particular portion of the rainbow in the garden, although all of them reflect some red light.

Pelar is the most reddish of the four, appearing as red, scarlet, or pink. Pelar colors garden geraniums, in which this form was first discovered and for which it is named (the Latin genus name is *Pelargonium*), as well as red radishes, strawberries, and passion fruits.

Cyan is next in redness, with just a hint of blue or violet, which makes it crimson or magenta. Cyan colors apples, blackberries, raspberries, cherries, currants, and the two most popular ornamentals, roses and tulips. Cyan is also the main anthocyanin in red dahlias, cornflowers, and blueberries.

Delph is the "blue" anthocyanin, although since it reflects some red and violet light, it can appear mauve. Delph colors the juice of pomegranate, the skin of eggplant, and many varieties of grapes. Most blue flowers, such as the delphinium (in which this form of anthocyanin was first found and for which it is named) are colored by delph.

Malvid, found mainly in dark or

black grapes and deep purple flowers, is the violet or purple anthocyanin. In addition, malvid is the most important pigment in producing the good "red" color of red wines.

Since many flowers and fruits can make at least three, and sometimes all four, of the forms of anthocyanin, the over-all color depends upon the proportions of each present. A wide range of hyacinth and verbena colors—from pale pink to deep purple—is a result of mixtures of cyan, pelar, and delph.

Several plants, however, can make only one form, usually cyan. This is true of the rose (and other members of the Rosaceae family, such as the apple, pear, plum, and strawberry). A clear blue rose is genetically impossible unless a chance mutation leads to the production of delph in the flower. Plant geneticists, however, by using the other means by which anthocyanin color is shifted toward the blue, have produced somewhat "bluish" roses.

Plant geneticists are also responsible for the more vivid colors found in garden flowers and fruits. Geneticists have bred the flowers and fruits for "high" color content, as well as larger size or other attractive characteristics. Since the quantity and proportions of pigments produced in the plant are genetically determined, many varieties revert to a "wild" type when left growing wild. The wild type produces sufficient color for natural purposes, but appears muted in color compared to specially bred varieties.

Although "white" may not be considered a color in the same sense as red or blue, plants produce a few minor pigments that contribute the whites and creams of flowers and fruits. These minor pigments absorb ultraviolet light and reflect almost all visible light, thus appearing white or cream. A white flower without these pigments would be transparent, rather than white, since light would not be reflected but would pass through it. Even in red or blue flowers, small amounts of these minor ultraviolet-absorbing pigments can occur. In fact, the attachment of this type of pigment to an anthocyanin molecule imparts a blueing effect to anthocyanin in some flowers, such as a "blue" rose.

Since a large number of the fruits and vegetables we eat are colored by anthocyanins and carotenoids, it is fortunate that both pigments are easily digested and metabolized. This is not true for one unusual pigment in the plant kingdom, betacyanin, the red pigment in beets and other members of the plant order Centrospermae. Unlike anthocyanins, which humans can easily digest and excrete colorless, betacyanin can present a problem. About 14 percent of the population have a genetic disorder that prevents their digestive systems from breaking down betacyanin and rendering it colorless. Following a dinner of beets, a person with this disorder will pass red urine and stools. Although this condition may appear alarming, it is not serious.

In the plant world, a substance—pigment or otherwise—is seldom produced without a selective purpose or function. As attractive as reds and blues are to the human eye, they are also inviting to other animals, which points to one function of anthocyanin coloring—the attraction of pollinating insects and birds. Bees, for example, which can distinguish four basic colors, are attracted first to blue and secondly to white flowers or flowers containing ultraviolet-absorbing pigments. (A bee can "see" the UV-absorbing pigment color even in a red or blue flower.) Color surveys of wild, insect-pollinated flowers in areas serviced by bees show a predominance of blue flowers, more than 50 percent of which are colored by blue delph. And in Europe, plant scientists have noted a definite evolutionary trend toward blue flowers.

Birds, on the other hand, are more attracted to red than to blue. In tropical climates, birds are more important than bees in flower pollination and red flowers colored by pelar and cyan predominate. Bananaquits and hummingbirds can be seen visiting the bright orange and scarlet-red flowers. Also, birds are important agents for seed dispersal from fruits, one reason for the predominance of red-colored fruits. Many other animals, including mammals, are also attracted to red and, by eating the fruits whole and eliminating the seeds in far-removed areas, play a role in seed dispersal.

In plants that are self-pollinated or pollinated by means other than insects or birds, anthocyanins are of less importance and, indeed, are less prevalent. Grasses, which are wind pollinated, generally have inconspicuous flowers lacking in anthocyanins. Several self-pollinated flowers also lack anthocyanin, although the occurrence of the pigment in some of these points to an ancestry of cross-pollination by birds or bees.

As far as is known, pigment molecules do not contribute to the smell of flowers and fruits. Aroma is produced by small volatile molecules that escape into the surrounding air

Before leaves die in autumn, they lose their chlorophyll, unmasking bright reds and yellows. These colors may also aid in protecting the plant and in producing energy.

and reach olfactory senses at a distance. Since all pigments are large molecules and thus nonvolatile, they do not reach olfactory senses. Some insects, however, may pick up the molecules when they pierce the flower or plant part and may be able to detect the molecules by a combination of taste and smell. Certain pigments could then attract the insect or repel it from further action.

If anthocyanin coloring were limited to flowers and fruits, the explanation of its functions as given above might suffice; but anthocyanins are also present in almost all green leaves even when not visible. In the growth cycle of most green leaves, the presence of red anthocyanin coloring is evident at two times: during initial budding and expansion, when the leaf is tinged with red or purple, and during senescence, when anthocyanin is unmasked by the loss of leaf chlorophyll, leading to a pageant of reds and maroons in autumn leaves. Cyan, the form of anthocyanin responsible for 93 percent of all red leaf color, is also the red pigment present in permanently red leaves, such as the red maple and the flowering plum.

Because it is present in so many parts of so many plants, a single, simple explanation for anthocyanin function seems unlikely. The very color of anthocyanin, red, may serve to repel certain insects, especially from tender budding leaves, just as it attracts other insects to the flowers. Also, there is currently some evidence that anthocyanins play a role in plant disease resistance, especially in leaf and seed tissues. One recent study on snap beans showed that red or spotted varieties of bean seed were more successful than white-seeded varieties at warding off an attack by fungus during germination. Unable to produce anthocyanins, the white bean is also unable to produce similar chemical substances that protect against fungi. The genetic pathways to production of these substances and anthocyanins are identical until the final steps.

Many aspects of plant growth, from the initiation of flowering to the beginning of senescence and death, are regulated by the quality and quantity of sunlight. Possibly, any pigment that interacts with light, absorbing light energy, can act as a mediator in some aspect of plant growth. Chlorophyll absorbs light energy and converts it into chemical energy. Carotenoids absorb some ultraviolet light and thus protect plant tissues from ultraviolet damage. Perhaps anthocyanins use the light energy they absorb for purposes scientific investigation has yet to determine. The presence of anthocyanin in so many plants and in so many parts of a plant suggests that it has some survival or selective value. The rainbow in the garden reflects more than color, it reflects the life and survival of the plants there. □

James Joern

Is Mars a Spaceship, Too?

by Lynn Margulis and James E. Lovelock

Even if the Viking *mission tells us little that we don't know, the results will be interesting*

One of the most ambitious and costly scientific projects ever undertaken will reach a critical stage this summer when two American *Viking* spacecraft enter Martian orbit. The *Viking* mission, which currently employs some 4,000 persons, has been under way since 1968.

Hopefully, the *Viking* landers will descend through the thin atmosphere and land softly on the red planet's surface. If all goes well in this extremely complex and uncertain experiment, the data should start coming back in July. The remote laboratories on the Martian surface—equipped with a battery of ingenious instrumentation—should send back information for months, possibly for more than a year.

The *Viking* mission has as a primary goal the answer to one basic question: Is there life on Mars? A NASA administrator put it less succinctly when he said, "Only through comparative studies of other planets and their evolution will man truly begin to understand the forces which shaped his own being and the world in which he lives."

Ironically, for centuries we probably have had a rudimentary understanding of "the forces which shape" life on a planetary scale, and our knowledge has expanded with recent findings in biochemistry, physics, and paleontology. This understanding is now known as the Gaia hypothesis (from the Greek *gaia,* meaning "earth"). If, as we believe, the Gaia hypothesis is correct, then we already know the answer to the basic question of the *Viking* mission.

The Gaia hypothesis states that the lower atmosphere of the earth is an integral, regulated, and necessary part of life itself. For hundreds of millions of years, life has controlled the temperature, the chemical composition, the oxidizing ability, and the acidity of earth's atmosphere.

The basic idea of the Gaia hypothesis is not new. In 1664, Philip Jacob Sachs de Löwenheimb used the widely accepted idea of water cycles between the heavens and earth as an analogy to champion William Harvey's theory that blood cycles within the human body. Today the theory of blood circulation is an accepted fact, but the significance of Sachs' analogy for understanding life on earth is barely appreciated. This may change shortly, because the *Viking* mission is, in effect, a test at a planetary level of the Gaia hypothesis.

The earth's atmosphere is a blanket of gas, about five miles high, in contact with the oceans, lakes, and rivers (the hydrosphere) and the rocky lithosphere. It has a mass of about 5,842,000 billion tons. The mass of the oceans—the other major fluid on the surface of the earth—is almost a thousand times heavier. Since the atmospheric mass corresponds to less than a millionth of the mass of the earth as a whole, small changes in the composition of the solid earth should cause large changes in the composition in the atmosphere; yet the atmosphere seems to have remained dynamically constant over long periods of time.

Where do the components of atmospheres originate? Some, like those of the outer planets Jupiter, Uranus, and Neptune, may be retained from the original gaseous material of the solar system. The atmospheres of inner planets probably formed from gaseous emissions of magma and rocks during their early history. The earth's atmosphere probably began to form from volatile materials that were retained by gravitational forces. The early history of the atmospheres of our neighboring planets, Mars and Venus, was probably similar to earth's. Although the atmosphere of Mars is cold and thin and that of Venus hot and dense, both consist of qualitatively similar elements.

In contrast, the atmosphere of the earth is strikingly different, even though it presumably shared a common history with its sister planets. It is anomalous in its composition, especially in the amount of oxygen and probably in its temperature. The earth's lower atmosphere retains measurable quantities of hydrogen and hydrogen-rich gases, such as methane and ammonia. These are light and tend to escape into space. This atmospheric hydrogen exists with the powerful oxidizing agent oxygen, and with methane and ammonia. Yet oxygen is an agent of their destruction. In fact, the entire atmosphere of earth consists primarily of nitrogen and oxygen—two elements that react with each other!

When hit by lightning or other forms of energy, these elements tend to form nitrate, a stable water-soluble ion that, with the abundant quantities of water around, ought to dissolve in the lakes, rivers, and oceans. Once dissolved, the nitrate should form nitrous and nitric acids, which in turn should lower the pH to far more acid values than the mildly alkaline pH 8.2 observed in the oceans today. If the Gaia hypothesis is true, we should be able to find evidence that this trend (predicted from the rules of chemistry and, indeed, observable on Venus with its hot acidic surface) is actively counteracted on the earth. A maintenance system, controlled by all organisms and powered by a great deal of photo-

By courtesy of the Wellcome Trustees

The frontispiece of a 1664 work draws an analogy between blood circulation in a body and water circulation in the atmosphere.

synthetically derived energy, regulates the reducing gases, the acidity–alkalinity balance, and many other features of the earth's atmosphere.

The past history of the earth with its extensive sedimentary record (fraught, as it is, with uncertainties in interpretation) provides some of the most convincing proof for the existence of continued biological modulation. If one accepts the current theories of stellar evolution, the sun, being a typical "main sequence" star, has substantially increased its output of energy since the earth was formed some 4.5 billion years ago. Some believe the sun has increased its output as much as 100 percent; most astronomers accept an increase of at least 25 percent since the earth was formed. Given solar radiation output and radiative surface properties of the planet, until about 2 billion years ago either the atmosphere was different (that is, contained more ammonia) or the earth was frozen. The most likely hypothesis is that the earth's atmosphere contained up to about one part in 100,000 ammonia, a good absorber of the sun's infrared radiation. Such absorbers let light in, but not out, leading to an increase in atmospheric temperatures. Other potential "greenhouse" gases apparently could not have compensated for the expected lowered temperature because they do not have the appropriate absorption spectra or would have been required in far too large quantities.

Atmospheric ammonia is rapidly photodestroyed (on a geologic time scale). However, ammonia was required to build amino acids, which were needed for life to originate. Good evidence exists for the presence of fossil life in the earliest sedimentary rocks, some 3.4 billion years ago. Therefore, ammonia must have been produced continuously by

microorganisms since early in the earth's history. There is no geologic evidence that, since the beginning of the earth's stable crust, the entire earth has ever frozen solid or that the oceans were volatilized. This suggests that the temperature at the surface has always been maintained between the freezing and the boiling points of water. Conditions have been continuously moderate enough for organisms ever since the biosphere came into existence, more than 3 billion years ago.

At least during the familiar phanerozoic (the last 600 million years of earth history for which an extensive fossil record is available), one can argue on paleontological grounds alone that throughout every era the earth has maintained tropical temperatures at some place on the surface and that the composition of the atmosphere, at least with respect to molecular oxygen, could not have deviated markedly. That is, there are no documented cases of any multicellular animals or green plants (out of about 3 million species) that can complete their life cycles in the total absence of oxygen.

All animals and green plants are composed of cells that divide by mitosis. The mitotic cell division itself requires oxygen. Thus it is highly unlikely that current concentrations of oxygen have fallen much below their present values in some hundreds of millions of years. Furthermore, since concentrations of atmospheric oxygen only a few percent higher than we now have lead to combustion of organic matter, including grasslands and forests, the most reasonable assumption is that the oxygen level of the atmosphere has remained relatively constant for long time periods.

Soils are made and lithified into sedimentary rocks. The formation of soil involves weathered rock particles interacting with communities of gas-exchanging microorganisms. Typical sedimentary rocks are known from the last 2 billion years to the present. This implies that oxygen and the other reactive gases have been maintained at stable atmospheric concentrations for time periods that are very long relative to their residence times. (Residence time is the time it takes for the concentration of gas to fall to 37 percent of its value; it may be thought of as "turnover time.")

How can these observations, which go against the rules of chemistry and physics, be consistently reconciled? The answer is incessant balanced production and removal by life—in other words, Gaia. Even though the absolute amounts of these gases may be very different during the history of the biosphere, the fluxes are remarkably similar. These reactive gases are produced and removed at similar rates. They are formed and used up primarily by nonhuman biological processes. Nearly all of them are produced and removed at a rate of hundreds of thousands of tons per year. This extensive gas exchange involves mainly the structurally most simple microorganisms, bacteria and blue-green algae. These rapidly growing and dividing masters of the microbiological world make up in chemical complexity and metabolic virtuosity what they lack in advanced morphology.

Precambrian microfossils suggest that microorganisms played a similar role in biogeochemical processes in the past as they do now. Current studies of their physiology suggest that they have an ancient history. The production and release of molecular

Some of Gaia's Mechanisms for Controlling the Atmosphere

Property Controlled	Method of Control	Possible Biological Mechanisms
Temperature	Absorption and reflection of visible light and infrared radiation by earth's surface.	Physiological control of plant pigments; shadow casting, soil formation, change of surface textures; darkening by uptake of water; lichen, algal and moss cover of rocks; trapping and precipitation of sediments such as limestone, carbon black, iron sulfides.
Temperature	Cloud cover by release of water into atmosphere.	Plant transpiration; effect evaporation by excretion of lipid and detergent coatings on water surfaces; bacterial and algal scums and slimes on water.
Temperature	Absorption and reflection of visible light by earth's atmosphere.	Emission of dust and aerosol precursors, such as terpenes, sulfur gases, ammonia; excrete salt particles that form from acid and base precipitates.
Temperature	Absorption of infrared radiation in the atmosphere.	Emission and removal of infrared-absorbing gases, such as NH_3, CO_2, H_2O.
Temperature	Circulation and heat transfer within the atmosphere.	Water evaporation and transpiration; emission of nitrous oxide and chlorinated compounds that could modify ozone layer denitrifying bacteria.
pH	Titration of sulfuric and nitric acids.	Control emissions from ammonia sources.
pH	Direct.	Some organisms excrete acids and bases (lactic, acetic, uric, nitric, and so on).
pH	Removal of carbonic acid.	CO_2 removal by blue-green algae catalyzes calcium carbonate deposits.
Oxidation state	Gases released or consumed.	Photosynthesis, respiration, bacterial production of hydrogen, methane, hydrogen sulfide.

oxygen into the atmosphere seems to have been an extremely important environmental determinant in the evolution of many forms of life. During the early period of the development of life 3.4 billion years ago, the earth teemed with oxygen-intolerant microbes. While these organisms would be termed primitive today, they performed a wide range of metabolic processes and were probably capable of greatly modifying the lower atmosphere. About 2 billion years ago, a group of microbes, the blue-green algae, were almost certainly responsible for the original change to oxygen-containing atmosphere.

We have tabulated some of the many possible tricks organisms have that may be mechanisms of regulation. We can do more than this, for although we see a phenomenon (the regulated atmosphere) we can only guess at the mechanisms of regulation. It is comparable to our original analogy: one can certainly show that temperature, salts, and bicarbonate ion in the blood are regulated without having the faintest idea of how the temperature and composition are kept constant. But like the blood physiologists, we begin to search for reasonable mechanisms that seem to be keeping the system in homeostatic balance in spite of many threatening perturbations.

Gaia probably circulates certain biologically critical elements—acids and bases, molecular oxygen, nitrogen and carbon and their compounds, sulfur and its compounds, and some others—in the atmosphere. We think microbial gas exchange is mainly involved in the circulation processes. The nonhuman biological contribution is generally far larger than the human contribution to both the "sources" (where the gases come from) and the "sinks" (where the gases are removed to). Sinks include reactions with surface rocks, removal by respiratory processes of organisms, and other resting places for gases removed from the atmosphere.

The cycling times for these major biological elements must be short because biological growth is based on continual cell division, which requires the doubling of cell masses in periods of time that are generally less than months and, typically, days or hours. On lifeless planets there is no particular reason to expect this phenomenon of atmospheric cycling, and on

the earth it is not expected that gases of elements that do not enter metabolism as either metabolites or poisons will cycle rapidly.

Because biological solutions to problems tend to be varied, redundant, and complex, the mechanisms of atmospheric homeostasis probably involve complex feedback loops. Since, for example, no volatile form of phosphorus has ever been found in the atmosphere, and since this element is present in the nucleic acids of all organisms, we are considering the possibility that the volatile form of phosphorus at present is totally "biologically particulate." This possibility is strengthened by the observation that the decaying bodies of salmon that migrate upstream to Alaskan lakes provide the limiting phosphorus for the algae growing in these lakes. It is these same algae whose growth provides food for next year's crop of young salmon. In this case, the nucleic acid and other cellular phosphates of migrating salmon can be considered the "volatile" form of the precious element phosphorus.

The earth's anomalous atmosphere can be best understood by the idea that it is a regulated integral part of the surface biology. Mars and Venus serve as the sterile, nonbiological planetary controls. If there is life on Mars, and if the Gaia hypothesis is correct, then our remote sensors should have picked up atmospheric anomalies there. They have not. We suspect the *Viking* landers will find no signs of life on the planet's surface either.

Failure of the *Viking* mission to find life on Mars will not prove the existence of Gaia, but it will add support to the hypothesis. Most scientific experiments are designed to disprove a hypothesis; when they fail the hypothesis is thereby strengthened. At great cost and effort, a rare planetary experiment for the Gaia hypothesis is now speeding toward a conclusion.

Given its atmosphere of a thin blanket of carbon dioxide, a little water vapor, perhaps argon, and a total absence of incompatible gases, we think that Saturday nights on Mars are not too lively. This summer we shall see.

Lynn Margulis teaches biology at Boston University; James E. Lovelock is a research physicist at Bowerchalke, Wiltshire, England.

Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun moves through the stars of Taurus until June 20, when it enters Gemini just before passing through the summer solstice. It stays in Gemini until July 20 and then enters the constellation Cancer. Its northerly position at this time of year gives us our longest days and greatest insolation, or received solar radiation. The earliest sunrise of the year is on June 13; the latest sunset is on June 26; and the earth is at aphelion, farthest from the sun, on July 2. The arrival of the sun at the summer solstice at 1:24 A.M., EST, on June 21 marks the beginning of summer in the Northern Hemisphere.

In June, first-quarter moon is on the 5th, full moon on the 11th, last-quarter on the 19th, and new moon on the 27th. In July, first-quarter moon is on the 4th, full moon on the 11th, last-quarter on the 19th, and new moon on the 26th. The moon will be at first-quarter again on August 2 and full on August 9. Perigee, where the moon is nearest to earth, is on July 6 and July 31. Apogee, farthest from earth, is on June 21 and July 19.

Stars and Planets No planets are shown among the stars on our evening Star Map for these months, even though four of them will be in the evening sky for all or part of the period. The reason is that all four will be so low in the west at sundown that, by the time it grows dark enough to see the evening stars of the map, the planets will have set. Two of them, Saturn, in Cancer, and Mars, moving from Cancer into Leo, will be easily seen low in the west at dusk. In June and early July Saturn is the brighter. Jupiter, in Aries, is the only planet well placed for viewing. Rising about midnight or earlier, it dominates the early morning sky in the east or southeast till dawn.

June 15: Mercury is at greatest westerly elongation, but poorly located as a morning star.

June 17: Venus is at superior conjunction, in line with but beyond the sun, and enters the evening sky.

June 23–24: Watch the moon pass from right to left of Jupiter from the morning of the 23rd to the 24th.

July 1: Mars can be seen to the right of the moon tonight. The brighter star to the left is Regulus, in Leo.

July 4–5: The bright star near the moon is Spica, in Virgo.

July 5: Uranus can be easily found with binoculars or a telescope, about 1° above the moon.

July 15: Mercury, in superior conjunction, enters the evening sky.

July 20–21: Jupiter is near the moon from shortly after midnight till dawn on both these nights. Mars is above the moon the night of the 21st.

July 28: The Delta Aquarid meteors reach maximum (up to 20 per hour but not very bright).

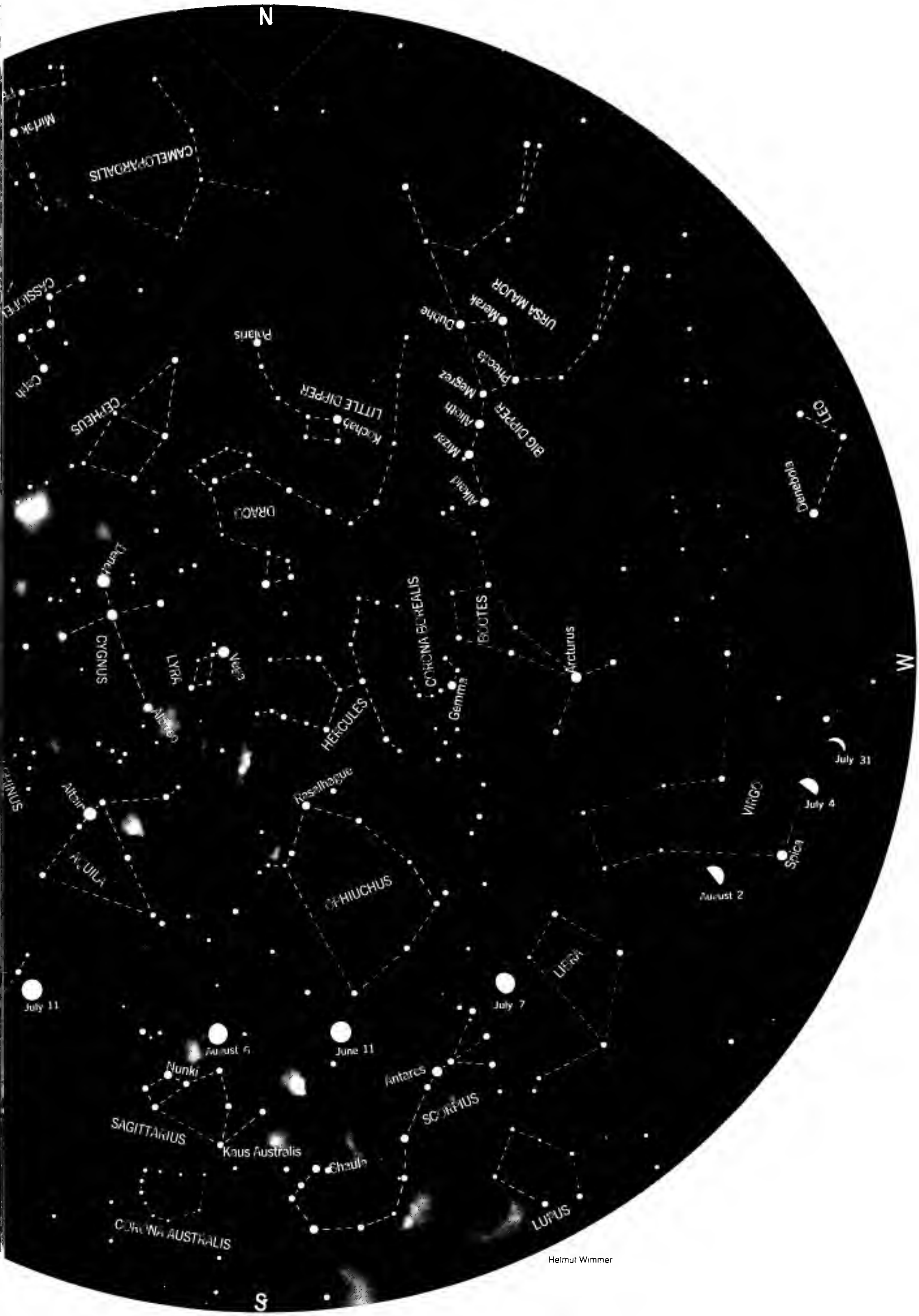
July 29: Saturn is in conjunction with the sun and enters the morning sky.

August 1: Spica is near the moon tonight.

August 7: Venus is becoming visible as an evening star.

August 10–13: Watch for the Perseid meteors on any of these dates from midnight until dawn. The best time will be early morning of the 12th, shortly after the shower reaches maximum, when you may see up to 50 meteors per hour, many of them quite bright.

★Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 12:20 A.M. on June 15; 11:20 P.M. on June 30; 10:25 P.M. on July 15; 9:20 P.M. on July 31; and 8:20 P.M. on August 15; but it can also be used for an hour before and after those times.



Helmut Wimmer

 by S. I. Rasool

The Venusian Surface

Data from soft landings on Venus have raised new questions concerning the planet's history

Seven years ago I wrote a full-length article for *Natural History* entitled "Venus, Star of Sweet Confidences" (June-July 1969). The piece, which discussed what had just then been learned about Venus from U.S. and Soviet spacecraft missions to that planet, ended with the sentence: "One [planet—the earth] developed into a prolific haven for life, the other [Venus] into a sterile, lifeless inferno."

In the last seven years, Venus has been visited by seven more spacecraft (six Soviet and one United States). All were successful in achieving their objectives and sent back a great deal of useful data. From these missions and earth-based telescopes we have learned that the surface of Venus, both in daytime and at night, remains simmering hot at about 800°F; the atmosphere is 100 times denser than that of the earth and is full of noxious carbon dioxide; and the planet has a heavy layer of clouds that may contain droplets of sulfuric acid. We have also found that Venus not only rotates backward (west to east) but revolves so slowly that one rotation takes 246 earth days. At the same time, in the upper reaches of the Venusian atmosphere, winds may rage at speeds exceeding 200 knots. These bizarre findings have whetted the intellectual appetite of planetary scientists to such an extent that an entire American space mission, made up of probes and orbiters, is now being specifically conceived and instrumented to answer some of the questions they raise. However, every time I talk about this high level of space activity concerning Venus, I am almost invariably asked, Why so much interest in Venus when it is a hot, sterile planet?

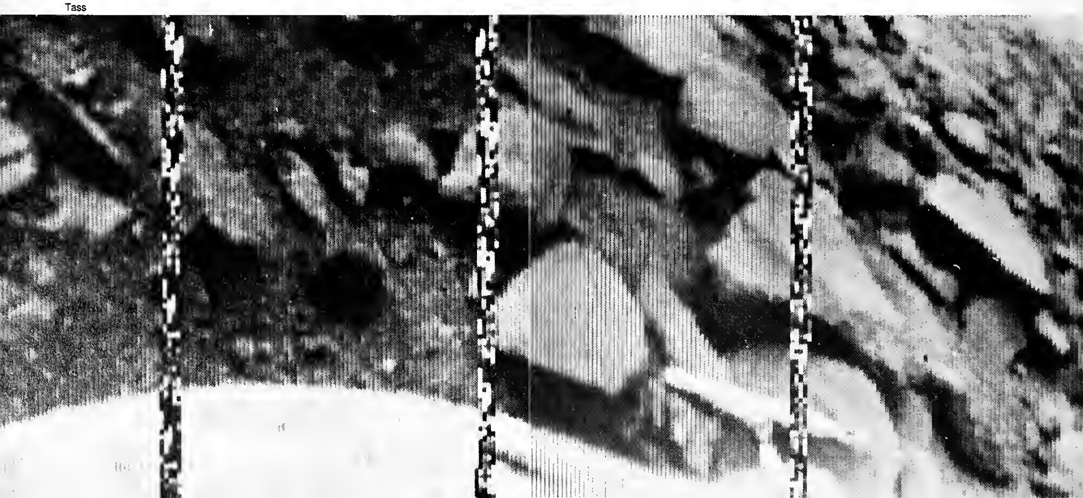
Let me try to answer this question. The principal reason for the scientific interest in Venus is precisely the fact that it is such an exceptionally hot planet. The problem becomes even more intriguing when we consider some other facts: Venus is almost exactly the same size and mass as the earth, it is located at about the same place in the solar system as the earth (being our closest planetary neighbor), and Venus and the earth probably formed at the same time and from the same mix of material as all the other planets. If Venus is made of the same material as the earth, is not much closer to the sun, and has approximately the same size and mass, why is its temperature close to 800°F while that on the earth averages a comfortable 60°F?

This fundamental question is related to the general problems of what controls the temperature on the surface of a planet? what determines the climatic change? and how stable is the earth's climate in the face of man-made pollution?

As we slowly progress in our experimentation and measurements on Mars, Venus, Jupiter, and the earth, we are beginning to probe deeper into the mysteries of climate. We have learned that the angle of the sun's rays, which determine summer and winter on the earth, may be entirely unimportant in the climate of Venus. Even the day-to-night differences in temperature that we are so used to on the earth may be nonexistent on Venus, despite the fact that the sun shines over the same side of Venus

This photograph of Venus, the first close-up of the surface of another planet ever taken, was made by the Russian spacecraft Venera 9 *on October 22, 1975.*

Tass



for 118 consecutive days. What, then, controls the climate of Venus? The answer lies in the chemistry of the planet's atmosphere: the Venusian atmosphere is about 100 percent CO_2, while the earth's atmosphere is mainly nitrogen and oxygen.

A carbon dioxide atmosphere has the special property of letting sunlight penetrate to a planet's surface, but not letting the heat escape. In much the same way as the glass cover of a greenhouse keeps the plants warm, an atmosphere made of CO_2 can heat up a planetary surface to a higher temperature than would normally be achieved by direct sunlight. Theoretically, this mechanism can explain Venus's measured high temperature of 800°F, about 600°F higher than it would be if Venus had an earth-type atmosphere. In practice, however, many of us have had difficulty in accepting this theory because the actual situation on Venus appears to be quite different from a simple, pure carbon dioxide atmosphere.

Venus is known to have an extended cloud cover, so permanent in nature that never in the long history of telescopic observations have any of the planet's surface features been seen. Even the highly sensitive TV cameras of NASA's *Mariner 10* spacecraft, which in 1974 passed by Venus at a distance of about 4,000 miles, could only delineate patterns in the clouds, but nothing below. From a variety of techniques, including earth-based radar, precise tracking of various *Mariner* spacecraft on their passage close to Venus, and the measurements made by the Soviet probes, we have been able to conclude that the surface of Venus lies about forty miles below the cloud tops visible from earth. But such questions as the following remain: What are the clouds made of? Do they extend all the way down to the planet's surface or do they exist only as a layer a few thousand feet thick like the cloud cover on the earth? What are the optical properties of the clouds? Does any sunlight filter through them and reach the surface? This last question is of paramount importance if the theory of the greenhouse effect is to explain the high temperature of Venus.

Some scientists have argued that no sunlight reaches the ground of Venus and that the planet's surface is shrouded in perpetual darkness. Their reasoning is as follows: first, we know that Venus has a substantial cloud cover; second, the atmosphere itself is a hundredfold more dense than the atmosphere of the earth; and lastly, even if the clouds do not extend down to the ground, there must be enough dust and "hot vapors" in the lower atmosphere to effectively screen the sunlight from the surface.

Other scientists have argued that the cloud cover may be thin or "broken" and the lower atmosphere pure enough to permit some diffuse sunlight to reach the surface. The proponents of a dark Venus had trouble explaining the high temperature at the surface and they invoked complicated dynamic processes in the atmosphere for the transfer of solar heat from the cloud level to the ground.

Soviet scientists seem to have been particularly interested in this problem. They included a light meter on a *Venera* probe that soft-landed on Venus in 1972 and reported that about 0.1 percent of the sunlight reaching Venus does penetrate down to the planet's surface. Intensive scientific discussion followed on how accurate these measurements were and what they mean in terms of the thermal structure of Venus's atmosphere.

The Soviets pursued this intriguing measurement further and equipped their subsequent *Venera* probes with cameras. Not sure whether the light level would be high enough for picture taking, the probes carried artificial illumination. On October 22, 1975, *Venera 9* soft-landed on Venus and transmitted the first close-up of the surface of another planet ever to be seen by a human eye. Three days later *Venera 10* landed about 1,500 miles from its sister spacecraft and sent back another picture. These two photographs are probably the single most important achievement of the entire Soviet planetary exploration program.

What do these pictures tell us about Venus? First of all the *Venera 9* picture of the surface contained surprises that have made planetary scientists reconsider their concepts of Venus. At a temperature of 800°F and under an atmospheric pressure of 1,400 pounds per square inch, it was assumed that rocks would long since have eroded away. What we see in the *Venera 9* picture is precisely the opposite: abundant piles of sharp-edged rocks. Soviet scientists have interpreted this to mean that the terrain shown in the picture is geologically not very old. Some say that the spacecraft landed on a mountain slope and the rocks may be fresh products of recent volcanic activity. The *Venera 10* picture reveals a landscape more like the one we expected to find on Venus—a smooth surface and gentle slopes with the depressions covered with fine-grained soil.

In addition to taking pictures, the landers measured the density and chemistry of the Venus surface. Data from these experiments show that the rocks may be basaltic, thus indicating that both the earth and Venus may have crusts made of volcanic material ejected from the interior.

Unfortunately, there is still confusion over whether the photographs were made in natural solar light or taken by the artificial illumination that was available on the spacecraft but, according to the first reports, was not used. If the pictures were made in solar light, how can we explain an intensity and directionality high enough to produce sharp shadows? On the other hand, if the floodlights on the spacecraft were used, why do the shadows point toward the spacecraft rather than away from it?

We hope some of these questions will soon be answered. But the fundamental question of why Venus became such a sterile planet and the earth a life-bearing one remains the most puzzling one in the planetary sciences. The answer will come only when we are able to reconstruct the history of planetary surfaces and their atmospheres. The American *Viking* spacecraft that are scheduled to land on Mars in early July will attempt to determine whether life ever evolved there. An entire U.S. orbiter-probe mission—*Pioneer*—is currently being designed for launch to Venus in 1978 in order to make precise measurements of the state of the Venusian atmosphere. Accurate measurements of its composition can be used to reconstruct the gross history of a planetary atmosphere.

As we enter the next decade, spacecraft will probe Jupiter with the same techniques. Each one of these measurements is a small piece of the big jigsaw puzzle: How did life on earth originate and what is the place of the earth in the universe? Hopefully, the pieces will soon begin to fall in place.

An authority on planetary atmospheres, S. I. Rasool is chief scientist in the Office of Space Sciences at NASA headquarters in Washington, D.C.

A LUXURY SEDAN BASED ON THE BELIEF THAT ALL OF THE RICH ARE NOT IDLE.

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Opulence often to the exclusion of all else: performance, efficiency, engineering intelligence.

50-70 mph, 5.9 seconds. "...high-speed passing acceleration borders on the brilliant," the editors of Motor Trend magazine.

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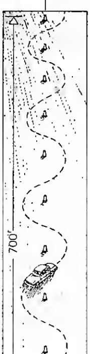
Beneath the hood of the BMW 530i is a singularly responsive 3-liter, fuel-injected engine that has been called by no less an authority than Road & Track magazine "...the most refined in-line six in the world."

Patented triple-hemispheric, swirl-action combustion chambers develop remarkable power from relatively small displacement.

And seven main bearings and twelve crankshaft counter-balance weights give the whole operation a turbine-like smoothness that never ceases to astound even the experts.



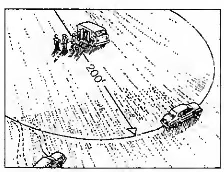
The 700 Ft. Slalom Test, designed by Road & Track magazine to measure lane changing capabilities. BMW ran the course at a remarkable 51.6 mph.

THE MAN WHO CONTROLS CORPORATIONS OUGHT TO BE ABLE TO CONTROL HIS OWN CAR.

If you're accustomed to the leaning and swaying one experiences in the conventional luxury sedan, you will thoroughly appreciate the uncanny road holding capabilities of the BMW 530i.

Road holding—driver control—is largely a function of a car's suspension system.

And, to be a bit blunt, BMW gives you a superior suspension system. Instead of the "solid-rear-axle" systems found in all domestic—and many foreign—sedans, the BMW suspension is fully independent on all four wheels.

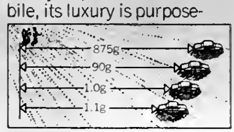


Results of the Motor Trend "200 Ft. Circle Test" clearly illustrate the superior road holding abilities of the BMW. At .82g BMW was still on the road, other makes were not.

And this, combined with a multi-jointed rear axle, allows each wheel to adapt itself independently to every driving and road condition—with a smoothness and precision that will spoil you for any other car.

A DECIDED LACK OF OPERA WINDOW OPULENCE.

While inside, the BMW 530i features as long a list of luxury items as one could sanely require of an automobile, its luxury is purposefully engineered to perform a very significant function: help prevent driver fatigue.



"...no detectable sign of (brake) fade. The more and harder they're used, the stronger they seem to get." The editors of Motor Trend sum up the results of their rigorous multiple-stop brake test.

All seats have an orthopedically molded shape. Individual seats are adjustable forward and back—with variable-angle seat back and cushion supports.

All instruments are clearly visible; all controls are readily accessible.

For many serious drivers in all parts of the world, the BMW 530i has redefined the meaning of the word "luxury" to encompass something more than a thin veneer of brocade and chrome.

If you'd care to judge for yourself, we urge you to phone your BMW dealer and arrange to take a thorough test drive.

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Dannon Yogurt. If you don't always eat right, it's the right thing to eat.

Every day, millions of people give up eating. For snacking.

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Our label shows you that Dannon is high in protein, calcium and other things nutritionists say are good for you.

It also shows that, unlike so many snack foods, Dannon is low in fat, contains no starch, no gelatin or other thickeners. And none of those hard-to-pronounce additives. Because Dannon Yogurt is 100% natural. Not just "natural flavor," but natural everything. No artificial anything.

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What's more, Dannon gives you the benefits of yogurt cultures. They make yogurt one of the easiest foods to digest, and have been credited with other healthful properties too.

Oddly enough, not all yogurts have any yogurt cultures to speak of. In some brands—mainly pre-mixed or Swiss Style—the cultures are often deactivated by the processing.

We created a whole culture of yogurt lovers.

Dannon outsells all other brands. For a number of good reasons.

For example, we go out of our way to get the best natural ingredients: to Eastern Europe for strawberries, to the West Coast for boysenberries, and we go to Canada for blueberries. (Maybe the reason that other yogurts don't come close to the taste of Dannon is that other yogurt makers don't go quite as far.)

And it's the yogurt delivered direct to your store "from Dannon to dairycase." So if it tastes fresher, that's because it *is* fresher.

Dieters aren't the only people who are big on Dannon®.

Today, almost everybody's eating Dannon. It makes a quick, delicious breakfast, a light but filling lunch, and of course you can't beat it as a high nutrition dessert or snack. Spoon it out of the cup as is, or mix with cottage cheese, fresh fruit, peanut butter, honey, or what-have-you.

A suggestion for beginners: since plain yogurt may be a bit tart, start with Dannon fruit yogurts—strawberry, blueberry, red raspberry, and others.

For more facts, including some unexpectedly delicious ways to eat Dannon, write for our booklet, "Yogurt and You." It's free.

If you are a dieter, by all means write for our 48-page guide, "Dieting, Yogurt and Common Sense." Just send 25¢ for postage and handling to Dannon, 22-11 38th Avenue, Long Island City, New York 11101. It will give you more reasons why Dannon is the right thing to eat—whether you are counting calories or not.

The Case of the Counterfeit Mice

THE PATCHWORK MOUSE: POLITICS AND INTRIGUE IN THE CAMPAIGN TO CONQUER CANCER, by Joseph Hixson. *Anchor Press/Doubleday, $7.95; 228 pp.*

Some years ago I received a letter from a gifted young biologist who was just finishing up his work as a graduate student at Berkeley, and with whom I had been talking about the kind of career he wanted to make for himself. In the letter he explained why he didn't want to be just a researcher, but to teach as well. "I think the instincts that lead a sensitive researcher to share his knowledge with others," he wrote, "and to test his thinking by dialogue with students, are certainly sharpened by a desire to retreat from the aspects of research, as it is presently practiced, that are antagonistic to the 'true' spirit of creative investigation—these being, primarily, publication without thorough investigation, covetousness of experimental data and ideas, and preoccupation with prestige."

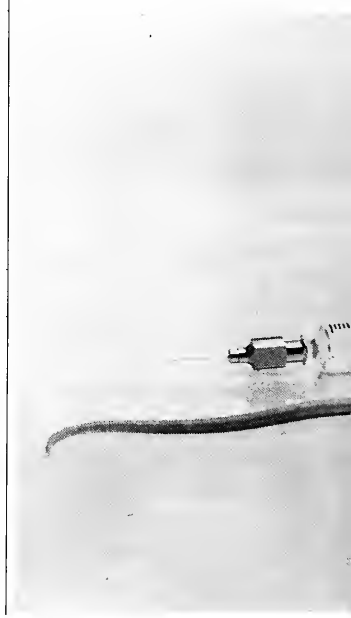
This letter was written in 1966, toward the end of a golden age for American science. Radar, penicillin, and, above all, the atom bomb had ushered in an era when scientists were seen (and often saw themselves) as holding the keys to national power and prosperity. To be sure, this striking change in the status of scientists, who had not previously figured very highly in the calculations of businessmen or generals or politicians, tended to corrupt science in the ways that my young friend found so depressing. But this corruption was to some extent contained or offset by the generosity with which American politicians were ready to lay out money to support the purest of pure research.

In those days almost any reasonably talented young physicist or chemist or molecular biologist could get such money as he needed to support whatever line of inquiry he chose to pursue. And he could get it without having to claim that he was laying the ground for the swift production of a new miracle drug or miracle weapon. Einstein hadn't been *trying* to invent the bomb when he worked out his famous equation, and scientists argued that the pursuit of knowledge for its own sake would, in time, pay off handsomely in practical results. Scientists had, of course, been saying

this for a long time. The difference was that in the 1950s and 1960s American politicians were for the first time buying the argument.

But in the 1970s pure science has suffered a sharp decline in the marketplace. Politicians have been impatiently asking when scientists are going to stop playing around and get to work on curing cancer and plugging us into solar energy. In many branches of science it is not enough for a researcher to impress his peers with his gifts as a scientist; if he wants money with which to exercise those gifts, he must hit on a project that can be advertised, however spuriously, as likely to yield quick practical dividends. In the circumstances, it is not necessarily the best scientist who gets the grants, but the one who best knows how to package, advertise, and merchandise his ideas.

Promoters and entrepreneurs are not new to science. More than a generation ago Einstein wrote that many who enter the temple of science do so simply "to make an offering of their brain pulp in the hope of securing a profitable return." Under different circumstances, he added, such scientists "might have become politicians or captains of business." But it is obvious that science, and particularly biomedical science, has become much more of a promoter's game than it was just a few years back.



It is this coarsening of American science, as it manifests itself in the field of cancer research, that is the theme of *The Patchwork Mouse.* Its author, Joseph Hixson, is an experienced science writer, who at one time handled public relations for New York's Sloan-Kettering Institute. He has chosen to get at his subject by carefully exploring the scandal that broke over this world-famous research center in 1974. At that time, it will be remembered, news got out that one of the institute's researchers had been faking the results of certain transplantation experiments that had greatly excited scientists both in this country and abroad. The researcher, a 35-year-old dermatologist named William Summerlin, had claimed, among other things, that he could graft the skin of a black mouse onto the back of a white mouse in such a way that the white mouse's immune system, contrary to all previous experience, would not reject the graft. If Summerlin's achievement could be confirmed it seemed certain to throw new light on how the immune systems of mice (and people) deal not only with skin grafts but with invading cancer cells.

As Hixson points out, it is still unclear whether Summerlin was or was not on to something significant. What is clear is that one morning, on his way to show his boss a cageful of

Rolf Bruderer

mice, he committed the unpardonable sin of taking out a felt-tipped pen and darkening some of his mouse skin grafts to make them look more convincing. A committee of his colleagues at Sloan-Kettering later concluded that he had also misled other scientists about his work on other occasions as well, and the unfortunate researcher was packed off to his suburban home on what amounted to terminal psychiatric leave.

Hixson relates in detail the events that led up to Summerlin's disgrace and the immediate repercussions. He examines—and allows the reader to make up his own mind about—the evidence to support Summerlin's plea of guilty-with-an-explanation. That explanation, widely reported at the time, was that he had been subjected to intolerable pressure by his chief, Robert Good, a world-famous immunologist who had brought Summerlin to Sloan-Kettering. According to Summerlin, Good had insisted that he come up at once with the kind of spectacular results that would be useful to Good in raising funds for the institute's research programs. Hixson also examines the contention of many scientists that Good was, in a different sense, at least partly to blame for Summerlin's transgression. In their view, Good had been so eager to claim vicarious credit for his protégé's work that he had ignored the gathering evidence that Summerlin was not to be trusted.

Hixson's account of the Summerlin affair takes up something more than half his book. The rest is given over to a concise history of cancer research and of the way it has been funded, leading up to President Nixon's decision to mount an all-out attack on cancer—an attack that many working biomedical scientists regard as wasteful and premature. Their argument is that the fundamental understanding of cancer that would permit a highly organized search for its prevention or cure does not yet exist.

Hixson gives us many interesting glimpses of scientific entrepreneurs and politicians at work. He is particularly knowledgeable about the ways in which an entrepreneur may take advantage of the news media's appetite for sensational scientific news in order to gain unwarranted publicity—publicity that can often be transmuted into money for the entrepreneur or his institution.

Yet even though Mr. Hixson

knows his subject and has his heart in the right place, *The Patchwork Mouse* is, in the end, disappointing. We get a lot of gratuitous personal details about Summerlin and Good, learning, for example, that "like Good's brisk baritone, Summerlin's tenor drawl wrings enthusiasm from his listeners." We are also informed that neither man "could or would call any man Mr. or any woman Miss or Mrs. after the first three minutes of conversation." But the author has little of significance to tell us about Summerlin's downfall that was not reported at the time. And he has succeeded only very partially in giving us what he promises in his preface, namely, a "behind-the-scenes account of the politics of cancer research in the United States." His book, it is true, includes some of the raw material from which such an account might be worked up. But too often, he fails to relate what he is telling us to a central argument or theme, and time and again the reader is engulfed in a quicksand of names, dates, figures, and blow-by-blow reports of bureaucratic sparring.

This is too bad, for the subject that has engaged Hixson is an important one. The task we face is not to drive the scientific entrepreneurs from the temple of science. There are, after all, forms of scientific enterprise that require the mobilization and deployment of small armies of scientists and technicians—smashing atoms with giant machines is a case in point—and it is hard to imagine how things could be set in motion without the talents of organizers and promoters. What we have to do, if we want science in America to flourish, is to see to it that there is also room in the temple for the untamed, solitary scientist; the scientist who wants neither to run a big research team nor to be part of one, and who justifies his disdain for quick practical results on the ground that man is distinguished from other creatures, not by the use he makes of the universe, but by his understanding of it.

Spencer Klaw is the author of The New Brahmins: Scientific Life in America. *His most recent book is* The Great American Medicine Show: The Unhealthy State of U.S. Medical Care, and What Can Be Done About It. *A frequent contributor to magazines, Klaw teaches at Columbia's Graduate School of Journalism in New York.*

by Raymond Sokolov

Best of the Brambles

Although fuzzy skinned and grainy textured, the raspberry is the most delectable of fruits

Unlike most of the more interesting fruits, the raspberry has no history. Columbus did not find it on Carib tables. Pizarro and Walter Raleigh did not cadge it from Incas or Oyana tribesmen. No one, to my knowledge, ever thought it was poisonous. The raspberry, it seems, was always there, growing around trees in the Alps and elsewhere in temperate Europe. But no one paid this queen of the brambles much mind, and it did not even have a name of its own until fairly late in the horticultural game.

The ancients lumped the raspberry with other juicy, fruiting brambles now conjoined in the genus *Rubus* (family Rosaceae, order Rosales). They do not seem to have troubled themselves to distinguish it in ordinary parlance from the blackberry. Today, we say, with more rigor, that the various thimble-shaped fruits of the genus *Rubus* (raspberries, blackberries, dewberries, thimbleberries, cloudberries, wineberries, Himalaya berries) are alike because they are all aggregate accessory fruits and not strictly berries at all. In other words, they are fleshy and grow in a cluster of little fruits, or drupelets (pulpy grains that are miniature versions of drupes like the peach with its soft outside and single, hard stone within), attached to a receptacle, or core, of the flower. True berries are small, simple fruits: grapes, tomatoes, gooseberries.

As between raspberries and blackberries, there are two main differences. Raspberry canes stand erect and reproduce vegetatively from suckers and root sections; blackberry canes arch over and propagate at the tip of the cane. More important, raspberries separate easily from partially dried receptacles at maturity. Blackberries have juicy receptacles and pull away whole, without separating from the receptacle. Blackberries are also grainier and they are black. The black raspberry (*Rubus occidentalis*) is also black when ripe. Raspberries can be yellow too, but the red raspberry we refer to when we say, informally, "raspberry" is *R. strigosus,* a hardy species that supplanted the species first imported here from Europe, *R. idaeus.*

Such precision of nomenclature is, perhaps, confusing in itself and not important to a family foraging in bounteous woodlands. They know what they like, and a *Rubus* by any name is still a berry and a good thing. But the thicket of Linnaean terminology is nothing compared to the tangle of popular names for raspberry that has grown up in European languages over the years.

No less an authority than Bailey's *Standard Cyclopedia of Horticulture* asserts that *raspberry* derives from *rasp,* a wood file, and *berry.* Now, the surface of our favorite aggregate accessory fruit does, in a way, resemble the multiple convex surface of a rasp, but the careful etymologist should not forget that the first reference to *R. idaeus* in modern English, in 1532, called the red-fruiting bramble a "raspis." This odd word must descend from *raspeium,* a term meaning "raspberry," dated to 1290 in Baxter and Johnson's glossary of medieval Latin drawn from British and Irish sources. Where *raspeium* came from is a mystery. It is not classical nor is it obviously related to other words meaning "raspberry" in other European languages.

Certainly, there is no connection with the Italian, *lampone,* or the German, *Himbeere.* The French, *framboise,* known in Old French of the twelfth century, undoubtedly is related to Spanish *frambuesa* and Dutch *framboos,* but where does it come from? There are those who suggest that the source is the Dutch word for blackberry, *braambes.* Another faction claims that *framboise* is a corruption of *fraisier du bois,* the strawberry of the forest, or wild strawberry. A pox on both their houses, and in this case that pox ought to be frambesia, the tropical disease known also as yaws and typified by frambesiform, or raspberry-shaped, lesions. On second thought, perhaps this is too strong an assault on harmless, if pettifogging, etymologists. Instead, let us resort to giving them the "raspberry," a form of flatulent Bronx cheer whose name evolved, in this century and at England's elite Eton College, into that generalized form of derision known as "razzing."

Enough of this frambesic jeering. The raspberry is a serious and wonderful thing, the stuff of gustatory reveries. Unfortunately, for the city dweller without a garden, the raspberry is a midsummer's dream that rarely comes true any more. The most delicious of all the fruits of the temperate zone is also the worst adapted to modern life. The raspberry does not travel well. Indeed, it is so fragile that pickers must be careful not to hold it too long, for it easily turns to pulp in the hand. Picking raspberries is also an uneconomical game of hunt-and-stoop among thorns, in summer heat. The whole fruit doesn't freeze well; frozen raspberries are the next thing to raspberry syrup.

For all these reasons, the fresh raspberry is a luxury crop. The U.S. Department of Agriculture does not even print figures for it in its bible, *Agricultural Statistics.* And those of us who insisted on early raspberries last season had to go to specialty

D. Overcash; Bruce Coleman, Inc.

grocers and pay $2 a half pint. The price did eventually fall, and we had some more, one at a time, with a small amount of sugar or a dollop of crème fraîche (heavy cream mixed with one teaspoon buttermilk per cup of cream and left to thicken at summer room temperature for several hours or overnight).

In late July, I found a handful of wild raspberries growing in a roadside patch. It was also possible to eliminate the middleman and appease my raspberry hunger, momentarily, by picking several quarts myself, for a derisory sum, in the backyard of an elderly rural couple.

The ideal solution to the raspberry shortage, however, is to grow one's own supply. It is too late now to plant a nursery shrub, but next spring, after the thaw, pick a plot of well-drained soil in partial shade. The plants should go in deep enough to cover the roots. Set them out in rows, with each plant two feet from the next. Keep the rows six feet apart, and try not to use soil that previously harbored tomatoes, potatoes, peppers, or eggplant, since the plot's past history predisposes raspberries to Verticillium wilt.

If you plant Everbearer raspberries, they will produce fruit the same year. Other varieties will not fruit until the second summer. In any case, when you plant, prune the cane back to two inches and protect the roots from dehydration with a six-inch mulch of peat moss mixed with one or two handfuls of fertilizer per bushel of peat moss.

Raspberries do not require cross-pollination. The standard plant has perennial roots and thorny biennial canes. Once the canes have borne fruit that second year, they should be pruned away. Good canes should be pruned to a height of four or five feet in the spring. Raspberry canes will stand erect by themselves, but some people find that it helps at picking time if they are trained to grow supported by a five-foot-high wire stretched between two stakes (or you could stretch two wires a foot apart, with canes supported in between).

These instructions apply only to the raspberry belt from southern Virginia to the prime northern areas of New York State and Michigan. There, the successful raspberry grower can look forward to as much as a decade of crops from a healthy plant. And on a quarter-acre patch, he can pick from 12 to 35 bushels. Most people will not be planting that many shrubs, but even a fairly modest patch will tend to inundate a single family. Raspberry jam is an obvious home remedy. Vera Gewanter and Dorothy Parker suggest, in *Home Preserving Made Easy* (Viking Press), that you can preserve the taste of the fruit by heating it almost to the boil, dissolving sugar in it (5 pounds for every 4 pounds of ripe, washed raspberries), and then sealing in warm jars.

Raspberries can also be used for sherbets, pies, Bavarians, mousses, and soufflés. Any large, standard cookbook will tell you how to make them. The best raspberry dish of all is that British jewel of simplicity, summer pudding (see recipe below). But, unsurprisingly, most of the complex ideas for raspberries are French.

The *Larousse Gastronomique* mentions, among many other extravagances, raspberry beignets, which are fritters made from a kind of doughnut batter studded with raspberries lightly sugared and macerated ahead of time with kirsch or raspberry eau-de-vie. The same list also includes *pannequets aux framboises:* dessert crêpes coated with pastry cream flavored with raspberry purée, then sprinkled with whole, macerated raspberries, rolled up, and heated in the oven at high heat.

Escoffier invented pêche Melba: vanilla ice cream topped with cold, poached peaches and sauced with a finely sieved purée of raspberries. This can also be done with pears or with an ice cream made from two pounds of apricots, crushed, sieved, sweetened to taste, mixed with 5 tablespoons of heavy cream (whipped) and 1 tablespoon of gelatin, and then frozen in the freezer compartment of your refrigerator. This recipe of the great Ali Bab (from *Practical Gastronomy,* McGraw-Hill) is called *abricotine aux framboises* and requires 1 pound of raspberries for the purée, which is sweetened to taste.

At Ammerschwihr in Alsace, the heart of the French raspberry country, where the best raspberry eau-de-vie is made, there is a great restaurant, Aux Armes de France, one of whose specialities is a *gratin de framboises.* In a greased, fireproof serving dish, they spread a layer of pastry cream flavored with raspberry eau-de-vie and lightened with heavy cream. Then comes a layer of fresh raspberries, which is sprinkled with chopped almonds mixed with a little sugar. Finally, they cover the fruit and nuts with another layer of flavored pastry

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cream. After being dusted with confectioners' sugar, the *gratin* goes into a 375-degree oven for three minutes.

For the raspberry picker too fatigued to think about any of these concoctions, *The Standard Bartender's Guide* (Pocket Books) has the answer, a raspberry cocktail. Soak a cup of bruised, fresh raspberries—the ones you don't know what else to do with—in 6 ounces of gin for 2 hours. Strain and mix with 1½ ounces of kirsch and 6 ounces of dry white wine.

Summer Pudding

1 small loaf white bread, slightly stale (see note)
2 cups raspberries
½ cup red currants
9 tablespoons sugar

1. Cut crust off the bread and discard. (If you are using unsliced bread, slice into quarter-inch slices.)
2. Line the bottom and sides of a 6-cup soufflé mold with the bread slices. Do not leave any chinks. Push the bread together at the joins.
3. Mix the raspberries, currants, and sugar together in a saucepan and bring to a boil. Reduce heat and simmer for three minutes. Let cool.
4. Pour off ½ cup of juice and reserve.
5. Put the cooked fruit mixture in the bread-lined mold. Cover the fruit with a layer of bread.
6. Put a plate that is just smaller than the opening of the mold on top of the pudding. Set a 3-pound weight on the plate.
7. Refrigerate overnight.
8. Just before serving, invert the pudding on a serving dish with a slightly turned-up rim. Pour reserved juice over the pudding.

Yield: Four servings

Note: Because of all the tinkering that has gone into store-bought bread, staleness comes on slowly and unnaturally in most cases. This recipe, adapted from an old chestnut collected by Elizabeth David, originally called for day-old bread. If you are using homemade bread, then one day is enough. With industrial bread, you may have to wait longer but don't wait until the bread is dry and stiff.

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*

Additional Reading

Environmental Law (p. 10)

Herbert A. Simon's *Administrative Behavior* (New York: Free Press, 1965, $2.95) is a classic study of bureaucracy in action. Although written more than thirty years ago, this scholarly work is still frequently used by schools of public administration for its illustrative accounts of decision-making processes and administrative organization. *The Logic of Collective Action: Public Goods and the Theory of Groups,* by economist Mancur Olson, Jr., (revised ed. Cambridge: Harvard University Press, 1971), is a fundamental guide to organized citizen action for the "public good." *Patient Earth,* edited by John Harte and Robert H. Socolow (New York: Holt, Rinehart and Winston, 1971, $4.95), presents case studies of eighteen celebrated environmental controversies, all of which involved citizen participation. The specific issues—construction of nuclear power plants, the south Florida–Everglades urbanization problem, the Mineral King resort project near Sequoia National Park—graphically illustrate the interplay of politics, economics, and science in environmental litigation. Joseph L. Sax's *Defending the Environment: A Strategy for Citizen Action* (New York: Random House, 1972, $1.95) explains how citizens can use the courts and the existing legal system in personal and collective efforts to clean up the environment.

Limits to Growth (p. 22)

The Limits to Growth, a summary account of the Club of Rome's Project on the Predicament of Mankind, edited by Donella H. Meadows et al. (New York: Universe Books, 1972, $2.75), has sold more than four million copies and has been translated into some thirty languages. Essentially a discussion prepared for a general audience, it details the implications of computer-modeling techniques applied to global growth dynamics. *Dynamics of Growth in a Finite World,* by Dennis L. Meadows et al. (Cambridge: Wright-Allen Press, 1974), is the 700-page technical report of the project. Dennis and Donella Meadows have also edited *Toward Global Equilibrium* (Cambridge: Wright-Allen Press, 1973), a collection of papers on environmental and resource issues, several of which deal with more easily grasped submodels—offshoots of the major limits of growth models. For example, "Population Control Mechanisms in a Primitive Agricultural Society," by Steven B. Shantzis and William W. Behrens III (pp. 257–88), recounts the application of system dynamics in the quantification of an anthropological description of a primitive slash-and-burn society. Michael R. Goodman's *Study Notes in System Dynamics* (Cambridge: Wright-Allen Press, 1974) will help with the complex methodology of model making. In *Collected Papers of Jay W. Forrester* (Cambridge: Wright-Allen Press, 1974), the author has gathered seventeen of his works, including two that are particularly related to his article: "Counterintuitive Behavior of Social Systems" (pp. 211–44) and "Churches at the Transition Between Growth and World Equilibrium" (pp. 255–69).

Manus (p. 60)

Margaret Mead's autobiography *Blackberry Winter: My Earlier Years* (New York: Simon & Schuster, 1973, $2.95) offers a personal perspective on America's most eminent anthropologist. Two of Mead's classic works, *Growing Up in New Guinea* (1930) and *New Lives for Old: Cultural Transformation—Manus, 1928–1953,* have recently been reissued (New York: William Morrow, 1975, $3.95 and $4.95, respectively). New prefaces add global perspective to cultural changes from the 1920s through the 1970s. *Continuities in Cultural Evolution* (New Haven: Yale University Press, 1964, $3.95) contains a chapter on changes in the life of one individual — Paliau—from living in a Stone Age culture to living as a "modern" man. "Peoples of the Pacific," a special supplement in the May 1971 issue of *Natural History,* edited by Margaret Mead and Preston McClanahan (pp. 34–70), discusses the variety of cultures found in the South Pacific. *World Enough: Rethinking the Future,* by Margaret Mead and photographer Ken Heyman (Boston: Little, Brown and Company, 1975, $17.50), is her latest book, an examination of the individual and collective dilemmas fac-

ing the contemporary world, revealed through the subtle interplay of Mead's anthropological insight and Heyman's searching photographs.

Catalina's Goats (p. 70)

Wildlife biologist C. F. Yocom's "Ecology of Feral Goats in Haleakala National Park, Manii, Hawaii" (*American Midland Naturalist*, 1967, vol. 17, pp. 418–51) details the impact of introduced goats on the flora and fauna of an island ecosystem. In "Goat Management Problems—Hawaii Volcanoes National Park: A History, Analysis, and Management Plan" (*National Park Service Natural Resource Report No. 2*, 1972, available from Superintendent, Hawaii Volcanoes National Park, Hawaii 96718), J. K. Baker and D. W. Reeser present a history of the introduction of goats to Hawaii, describe the subsequent ecological damage and attempts at control, and discuss the public and political pressures inherent in goat–habitat–people interactions. "The Influence of Feral Goats on Koa Tree Production in Hawaii Volcanoes National Park," by G. Spatz and D. Mueller-Dumbois (*Ecology*, 1973, vol. 54, pp. 870–76), is a study of goat damage to a specific type of tree, exploring such definitive parameters as tree height, sucker growth, and regeneration dynamics. For a detailed description of goat behavior, see "Some Aspects of Social Behaviour in a Population of Feral Goats (*Capra hircus* L.)," by Chris C. Shank (*Zeitschrift für Tierpsychologie*, 1972, vol. 30, pp. 488–528).

Plant Coloration (p. 78)

Residential Plantings, edited by Anthony Tyznik (Chicago: J. Philip O'Hara, 1969, $3.95), illustrates changes in plant and tree coloration throughout the growing season. Patricia W. Spencer's "The Turning of the Leaves," (*Natural History*, October 1973, pp. 56–63) describes the emergence of characteristic leaf colors after the seasonal loss of chlorophyll and the internal and external biochemical changes that accompany leaf senescence. *Chemistry and Biochemistry of Plant Pigments*, edited by Trevor W. Goodwin (New York: Academic Press, 1965), contains an excellent introductory chapter on plant coloration. Jeffrey B. Harborne's *The Comparative Biochemistry of the Flavonids* (New York: Academic Press, 1967), although highly technical, is a source of information on the anthocyanids. *Advances in the Chemistry of Plant Pigments*, edited by C. O. Chichester (New York: Academic Press, 1972), presents a series of papers on plant coloration, ranging from general overviews to highly technical accounts. Two articles in *Scientific American* will also be useful: Sylvia Frank's "Carotenoids" (1956, vol. 194, no. 1, pp. 80–86) and Sarah Clevenger's "Flower Pigments" (1964, vol. 210, no. 6, pp. 84–92).

Gordon Beckhorn

Announcements

A new permanent hall—**The Hall of Minerals and Gems**—opened in May. Located in the southwest corner of the first floor of The American Museum of Natural History, this is a most spectacular and elegant hall, with an impressive array of minerals, gems, rocks, and meteorites. For a limited time, it will house a special exhibit of nine world-famous, American-owned diamonds, including the Tiffany Diamond valued at $5 million, the Eugenie Blue, a heart-shaped diamond reported to have belonged to the Empress Eugenie, and the Zale Light of Peace. This hall, the largest in the Museum, treats major subjects such as properties of minerals, mineral-farming environments, systematic mineralogy, interaction of minerals and energy, and esthetics of gems.

This Exhibit in Preparation continues through July in Gallery 77 of the Museum. This show gives visitors a "behind the scenes" look at the techniques used to create the Museum's many marvelous dioramas and exhibits. Graphics, three-dimensional displays, and demonstrations by artists, taxidermists, preparators, and model-makers reveal the inner workings of the Exhibition Department.

The **Alexander M. White Natural Science Center** on the second floor of the Museum is open from 2:00 to 4:30 P.M. Tuesdays through Fridays, and from 1:00 to 4:30 P.M. Saturdays and Sundays. This exhibit area is designed to re-create and explain the nature of New York City to children ages 8 to 12. "Show and Tell" exhibits depict how city dwellers get their food, water, and electricity; how they communicate (via more than 25 million miles of underground telephone wires); and who their neighbors are (countless insects, fishes, birds, reptiles, and mammals). It presents the city's parks, its sounds, and the ecology of surrounding bodies of water. Emphasis is on how these natural and man-made elements are integrated to make up the environment in which urban children live.

At the **Hayden Planetarium** of the Museum, "Things That Go Beep in the Night" continues through June 28. The invention of radio astronomy in the 1930s opened a new window to the universe, enabling astronomers to "listen in" on distant galaxies, exploding stars, pulsating stars, quasars, and black holes. Starting June 30, "Yankee Stargazers" will continue into September. This show recounts contributions by Americans to the knowledge of the universe—from the first astronomical observation in the New World (in 1494) through New York physician Henry Draper's photographing the sky in the mid-1800s, Karl Jansky's discovery of radio waves coming from space in 1932, man's landing on the moon in 1969, and the first landing on Mars in the summer of 1976. Shows begin at 2:00 P.M. and 3:30 P.M. on weekdays with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children and students (special rates for groups and senior citizens).

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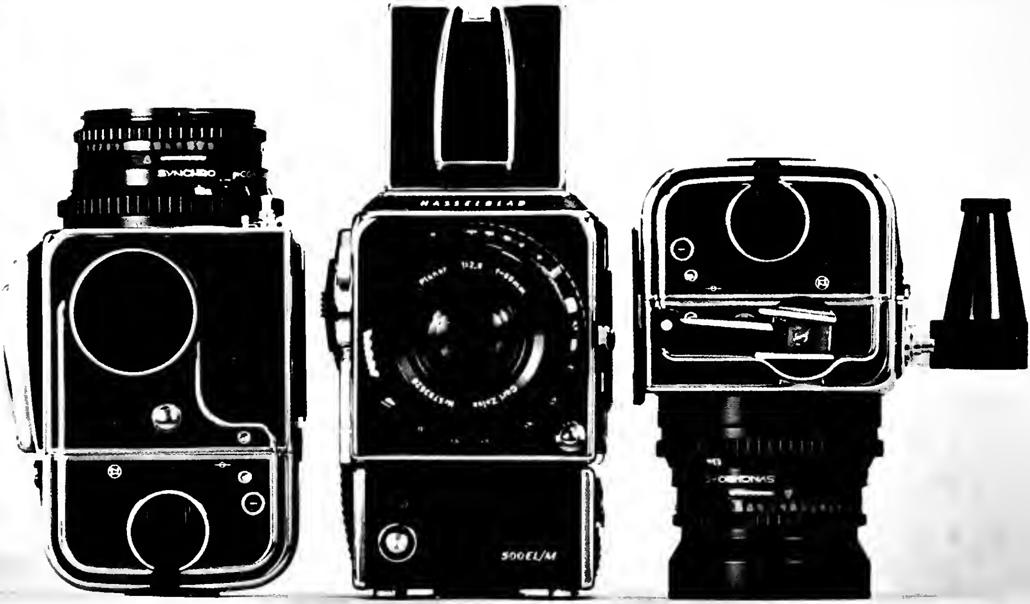
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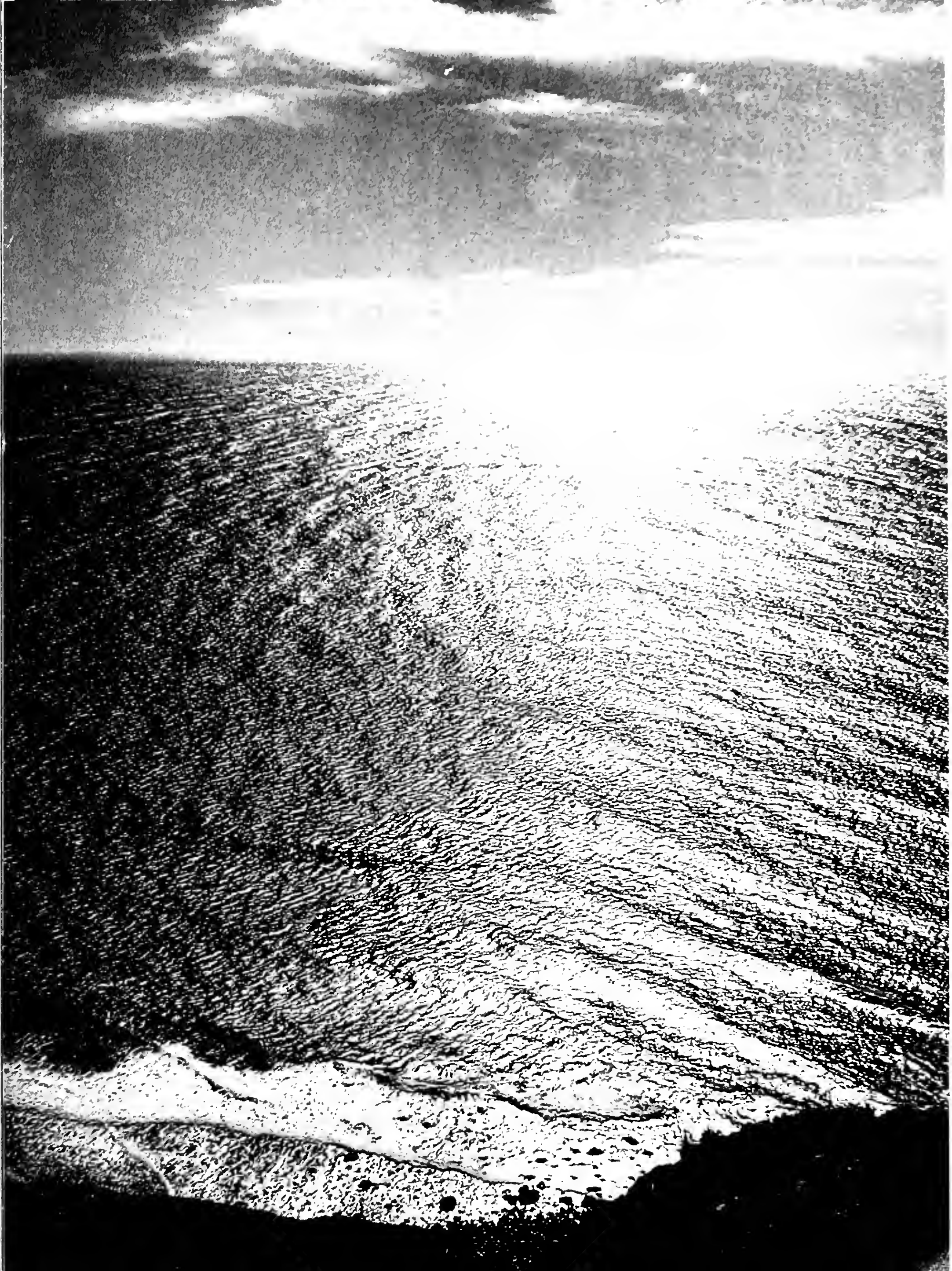

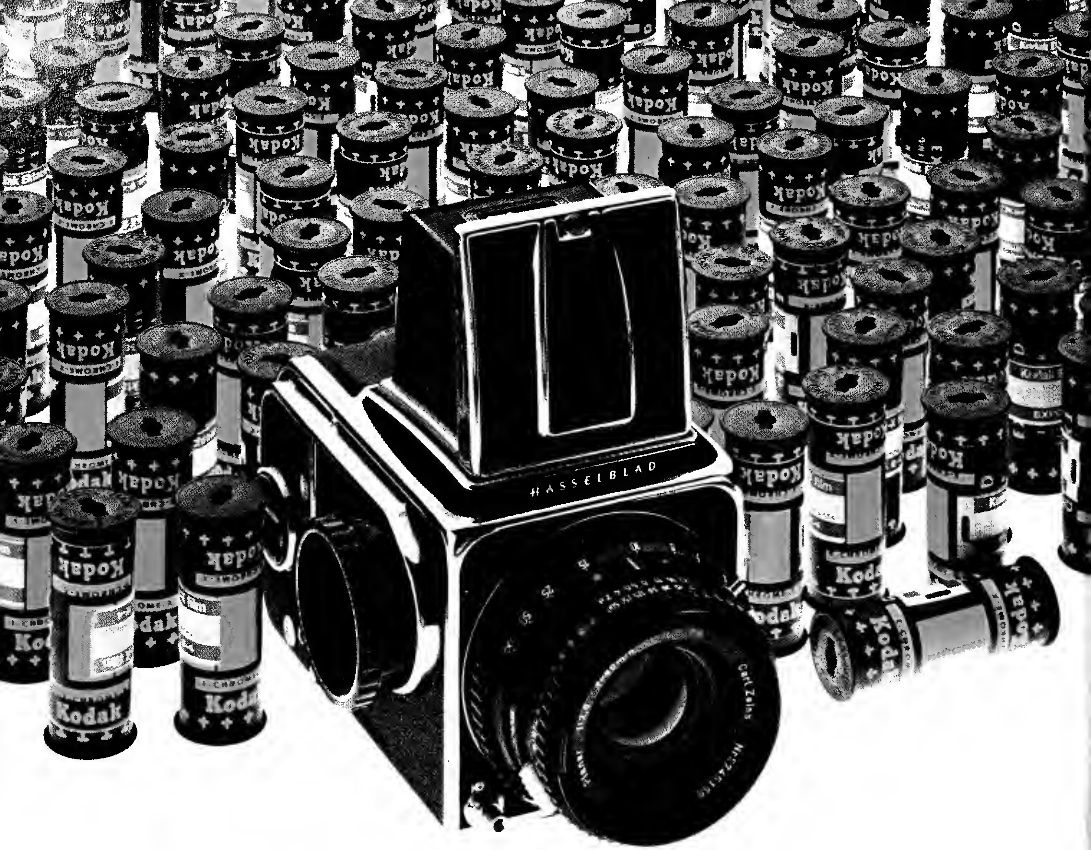

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We have, in the few centuries since, found more pebbles and shells, but the "great ocean" remains untarnished.

This special bimonthly issue, which appears when so many people turn to the shores for vacation, for re-creation, is dedicated to the oceans. It looks at some of the forces that created them and at those that drive them. We introduce a few of the many creatures that play out their life cycles in the seas—and every author admits how little we know about any species, much less that vast array of life within the ocean ecosystem.

Finally, we turn to some of the basic decisions—political, economic, and humanitarian—that the nations and peoples of the world must now make about the future of the oceans.

NATURAL HISTORY

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Authors

A former newspaperman and public information officer, **W. Redwood Wright** is now a senior oceanographer at the Northeast Fisheries Center of the National Marine Fisheries Service. He switched from public information to science following two months on a Danish icebreaker investigating deep circulation in Greenland waters. Wright earned his Ph.D. degree in physical oceanography from the University of Rhode Island twenty years after completing his undergraduate work at Princeton. He hopes in the future to spend time at sea again to gain information about the variations in continental shelf circulation and their effect on fish stocks.

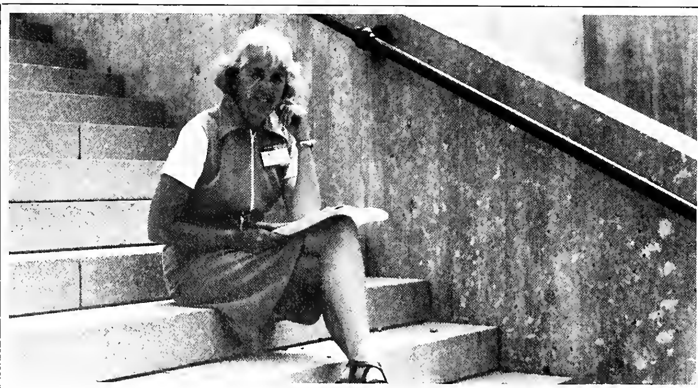
John F. Palmisano first went to the Aleutian Islands as part of an interdisciplinary team that was studying the effects of underground nuclear tests on the marine environment of Amchitka Island. Interested in the distribution of coastal marine organisms, he began to focus his research on sea otters as he realized their importance in shaping the nearshore community. This work led to a dissertation on otters and to his Ph.D. in fisheries ecology from the University of Washington last year. Palmisano is now an intertidal ecologist with the National Marine Fisheries Service at Auke Bay, Alaska. Coauthor of the article on sea otters, **James A. Estes** has been studying these animals since 1970. He, too, has centered his field research in the western Aleutian Islands, but hopes to study the ecology and evolution of nearshore communities in other areas as well. When not observing otter predation *in situ* or off on a Russian ship assessing Pacific walrus populations—his latest project—Estes is a research biologist at the National Fish and Wildlife Laboratory in Anchorage.

An assistant research biologist at the Marine Science Institute of the University of California at Santa Barbara, **Bruce H. Robison** has centered his oceanic research on the midwater fishes of three Indo-Pacific seas and their niche distinctions. He has spent more than two of the past nine years aboard a variety of research vessels on expeditions to many of the world's oceans and has conducted hundreds of deep-sea trawl hauls. Of his most exciting experience—a dive in the three-man submersible *Alvin,* which took him to a depth of more than a mile in the Atlantic—he writes, "The textbook image of an oceanic water column that had been in my mind was erased as the real thing slid by my window. It was like going to the moon in the way it changed my perspectives."

Animal behaviorist **Michael Berrill** initially chose mysids, small shrimplike crustaceans, as his particular interest but switched to lobsters when he got tired of explaining what mysids are. He also decided that lobsters "taste too good to disappear, lamented but unknown." An associate professor of biology at Trent University in Ontario, Canadian-born Berrill is continuing his research on the behavioral ecology of freshwater crayfish and marine lobsters and will expand the scope of his studies to include the antipredatory behavior of these animals. He wrote "Benthic Life in the Fjords of Norway," for the November 1970 issue of *Natural History*.

A prolific writer on ornithological subjects, **Paul A. Johnsgard** is currently studying the taxonomy of grouse, quails, and ducks. He has done extensive investigations of waterfowl and his field work has taken him to virtually all areas of the Western Hemisphere. He is now compiling and editing a catalog of classic American bird decoys, *The Bird Decoy: An American Art Form,* which will be published by the University of Nebraska Press this fall. A professor of zoology at the University of Nebraska, Johnsgard has published many articles in *Natural History;* the most recent being "Quail Music" (March 1974).

Marginal seas are oceanographer **David A. Ross**'s speciality. He has been on three expeditions to the Red Sea, two to the Black, and one to the Mediterranean to study the marine geology and geophysics of these basins. Next year he plans to do research in the Persian Gulf and the Gulf of Aqaba. For the past seven years Ross has been an associate scientist at the Woods Hole Oceanographic Institution in Massachusetts. In addition to his scientific work, he teaches at the Fletcher School of International Law and Diplomacy at Tufts University and at Massachusetts Institute of Technology. One of Ross's hobbies is speed ice skating. He was second in his age group (35–39) in the 1976 Senior Olympics in four distances in that event.



Beatrice M. Sweeney has been observing red tides off the coast of southern California, in the West Indies, and in New Guinea for almost twenty-five years. She was one of the scientists invited to give a paper at the First International Conference on Toxic Dinoflagellate Blooms held in Boston in the fall of 1974. A native New Englander, Sweeney received her doctoral degree in biology from Radcliffe College. A long-time resident of the West Coast, she teaches in the Biology Department of the University of California, Santa Barbara, and enjoys snorkeling when time permits.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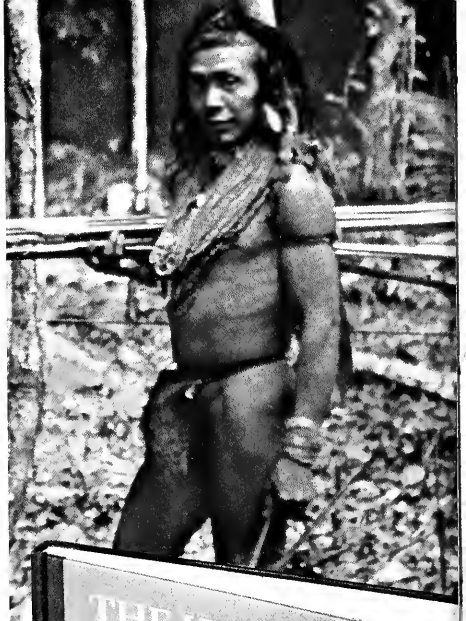

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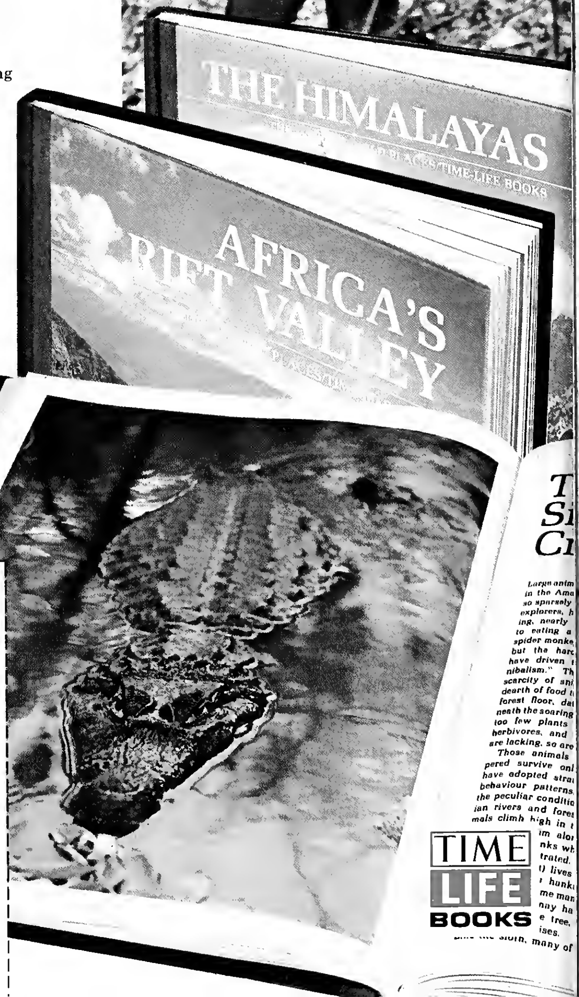

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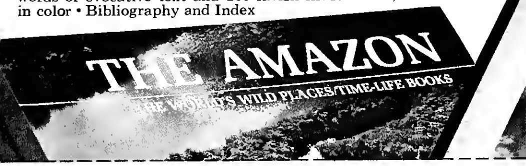

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Fishing the Commons

A crowded world dictates the necessity of regulating the continued exploitation of ocean resources

As humanity seeks to wrest food from the sea, species after species of marine animal approaches extinction. Since the beginning of this decade the gross harvest of fish has fallen, an indication that we are exploiting this resource beyond its point of maximum sustainable yield. Man's response has been to try harder—an action more suicidal than sapient.

We are caught in a semantic trap; the shibboleth of "freedom of the seas" inhibits thought. It is dangerous in our time to question the word *freedom*, but we must. Some implications of the spontaneous phrase "freedom of the seas" are defensible: the right of passenger ships, for example, to traverse the sea at will. But what about the right to pollute at will? Or to mine sea beds for minerals? Or to fish the oceans' populations to extinction? Surely there are rational limits to these freedoms. Collective humankind has failed to agree on the limits. Very well, then, let us admit our failure and try to discover its cause. Why have we failed? What unexamined propositions cause us to repeat our failure, time after time?

By now it should be clear that no technological remedy will save the seas as a source of wealth. Every improvement in fishing gear or mining equipment merely hastens the day of exhaustion. Our problem is not a technological one but a social and political one. We must try to understand human systems, particularly politico-economic ones.

Conventional wisdom holds that the world has two major politico-economic systems—one often referred to as democratic and the other as totalitarian. England and the United States exemplify the first type; Russia and China the second. The labels given these two systems are troublesome: capitalist or private enterprise is assigned to the democratic countries, while centralist, communist, and socialist are used for the totalitarian ones. Most countries, however, are mixed economies: Russia has a bit of capitalism in her system and the United States is more than a little socialistic. But conventional wisdom says that in their pure forms only two systems exist.

Conventional wisdom is wrong—there are three. The third system is that of the commons. It is a cryptic system—seldom named and seldom recognized. The oceans have always been governed by the system of the commons, which may work well so long as the world is not overloaded with human beings. But once the world becomes crowded, adherence to the commons becomes suicidal.

Suppose the oceans were managed and controlled by a capitalist nation as a sort of private enterprise. Suppose nation X possessed the right and power to exclude entrance to and exploitation of the oceans. It might well keep all other nations from fishing. What would happen to the fish stocks? If X was farsighted and had accurate information about the population dynamics of marine species, it would control its fishing efforts so as to obtain the maximum sustainable yield, year after year. Any other policy would be unwise and contrary to its own long-term interest.

Is ownership of the seas by one nation a responsible method of regulation? Most people, repelled by the thought of such national ownership, would call it unjust, and for the purposes of this argument, let us agree. But if within the framework of this unjust system, X's decisions are wise ones, the nation benefits. If they are unwise, X pays the price, perhaps in the next generation. The system, although unjust, is responsible and will reward the nation that makes wise decisions and punish it for unwise ones. Conceivably, ocean fisheries owned as a private enterprise could be well managed indefinitely.

This is also possible for a socialistic system. Without creating an all-purpose world sovereignty, we may some day be able to create an international agency with sovereignty limited to marine fisheries. Since the world's population of four billion people could hardly come together in a town meeting to agree whether the halibut catch should be increased or the fur seal harvest diminished, nations collectively would have to agree to turn the management of the oceans over to a commission.

Most of us would call this a more just system than ownership by only one nation. The world population would either benefit or suffer from the managing commission's wise or unwise decisions. But under this system it is also conceivable that the ocean fisheries could be so managed as to yield abundantly far into the future.

I have emphasized what might be called the normal physiology of the two politico-economic systems, but they also have their pathologies. Private enterprise may abuse its power. Under socialism, managers are not always honest. By nature, the managers of a socialistic system usually have first access to information concerning the functioning of the system. With the discovery of a miscalculation, a commission may be sorely tempted to bottle up the incriminating information. Freedom of information becomes a primary problem. Consider the behavior of any nation's defense department—an inescapably socialistic institution no matter the nominal form of government. Every such establishment seeks to prevent public knowledge of flagrant cost overruns by suppressing information

in the name of national security. The ancient Romans wisely asked, *Sed quis custodiet ipsos Custodes?*—"But who is to guard the guards themselves?" To this day we have no general answer to this problem, but must improvise as we go along.

The relative merits of socialistic and private enterprise are not our concern here. Our concern is with the third political system, the system of the commons. Both socialism and capitalism can conceivably work well in a crowded world. Not so with the system of the commons, which in a crowded world inevitably works toward a tragic end. Today we are seeing this occur before our eyes in the death of ocean fisheries. Under the system of the commons, the exploitable resource is regarded as common property but, unlike socialism, the resource is not managed. The use of the commons is governed by the Marxian principle "to each according to his needs," where "needs" are determined by each person or nation.

This is the system under which the oceans have always been exploited. When people were not numerous it worked. But now that there are four billion of us this system does not—and cannot—conceivably function. Ruin is the end result of the normal physiology of this system.

Suppose a nation exploiting fisheries under a commons system realizes that fish stocks are dwindling. But because it is short of protein, the nation considers stepping up its fishing effort. Is this a rational policy or would there be more benefits if the nation decreased its efforts? The answer is mixed. Increased effort will bring an increased harvest in the short run. But in the long run stocks will decrease, resulting in less catch for the same effort in subsequent years.

It is important to note, however, that the nation that initially decides to increase its fishing efforts will be the sole one to benefit, whereas all the nations that fish in the commons share in the eventual loss. The traditional doctrine of freedom of the seas necessarily implies (although it is never explicitly stated) that the decision-making nation does not have to answer to the other affected nations.

Even worse, the nation that makes a decision that in the long run is detrimental to others as well as to itself is rewarded in the short run. The system of the commons thus rewards for the worst decisions. That is the reason why oceanic fisheries are doomed if we cling to the notion of freedom of the seas.

If the system of the commons were specifically labeled as a system, it would be open to attack; perhaps this is the reason it has escaped classification. Capitalism branded as such invites attack, as does socialism or, for that matter, any other "ism." But the system of the commons has no recognized ideological label. It is protected from attack by the rubric "freedom," which implies that we are dealing with something that transcends ideology. Nevertheless it is an ideology, and "to each according to his needs" defines it. And it doesn't work.

Faced with such a situation, inveterate optimists may call upon conscience and wish to appeal to all nations for restraint. In a theoretical sense, such an appeal is logical; in a real sense, however, it would be a weak solution. There are about 150 nations in the world. For a system of voluntary restraint in the commons to work, three conditions would have to be met: accurate factual information; perfect agreement on the interpretation of the facts, including proportional distribution of the harvest; and absolutely no cheating.

In the real world there is little possibility of all three conditions being met. For more than a quarter century the International Whaling Commission has informed its member nations that whaling efforts must be reduced, but to no avail. Scientific data have been disputed and recommendations flouted with the predicted result, namely, depletion of the whale stocks. Still the carnage goes on. Now only two whaling nations remain—Russia and Japan. Their internal affairs are governed by the two opposing classical systems, socialism and capitalism. But as far as whaling is concerned, they operate by the ideology of the unmanaged commons. Only destruction lies ahead for the whaling fisheries. Neither nation is willing to prevent this by acknowledging that the future of the industry necessitates its immediate reduction; to do so would be to hand all the benefits to its competitor.

If voluntarism does not work when there are only two countries in the game, what chance can it have when there are scores of nations involved, as is true for the other fisheries? It takes only one uncooperative nation to ruin an unmanaged commons. Reality dictates that we reject as unworkable any politico-economic sys-

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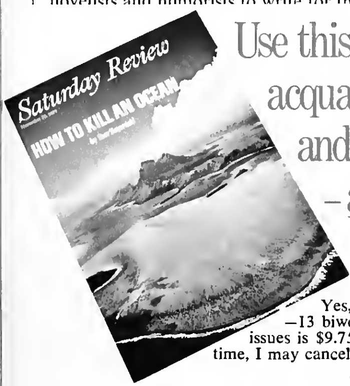

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tem that depends on the perfection of all its decision makers.

Perhaps public opinion can create the needed conscience among all participants in a commons but this seems doubtful. For some time we have called the Japanese greedy for killing whales at so great a rate. Insofar as they reply, they point out their land-poor population's need for protein. "Need creates right" is the automatic assumption of any overpopulated country.

If the cry of "greedy" is of any use at all, it is as a means of rallying the troops of the critics to use other means of coercion, such as a boycott of imports from the accused nation. If this method works at all, it does so, not through a call to conscience on the part of the accused nation, but through an economic pinch.

How is it possible to indefinitely exploit, and at the same time maintain, the ocean's renewable resources? (The mining of nonrenewable minerals is a rather different problem, not considered here.) If we had a choice, most of us would probably opt for a socialistic system because it appears to most easily serve the cause of justice. But each maritime nation feels strongly about its right to exploit the oceans without restriction. And even if the necessary majority of powerful nations agreed to a limited encroachment of what they perceive to be their rights, it is not clear what principles of distributional justice should be followed by the management they might elect. Should land area be the deciding factor in dividing the wealth of the oceans? Or should such division be based on population, wealth, amount of malnutrition, or tradition? These are difficult questions and no matter what options are available, the argument might be impossible to settle.

At the moment the private enterprise approach is likely to make more progress. For centuries we have exploited the oceans through a tradition of national sovereignty. It is easier to extend an old tradition than to suppress it—which we would have to do to create fisheries based on socialism. Nation after nation has extended this tradition by favoring a 200-mile limit to national coastal waters, instead of the traditional 3- or 12-mile limit. By this extension, a nearly 200-mile-wide strip of oceanic commons next to each maritime nation will be converted into private property as far as fishing is concerned. This will not solve all the problems. A nonmigratory species of fish may be protected by this change, but not a wide-ranging one. And open ocean species will be no better off.

Some aspects of the 200-mile limit are ludicrous. Honduras owns two islets, the Swan Islands, in the Gulf of Mexico. On the basis of this tiny bit of real estate with a population of 22 people, Honduras could theoretically claim exclusive fishing rights to 126,000 square miles of ocean—the area of the 200-mile radius surrounding the islets.

The British island of Dominica and the French island of Martinique are less than 30 miles apart. What will happen to fishing rights in this region? Presumably a line equidistant from the nearest points of the two islands would be drawn. Three neighboring islands under three separate jurisdictions creates a situation even more difficult to solve. International lawyers will be kept busy for some time pondering these complex issues.

Also at issue is the apparent injustice of giving greater fishing rights to maritime nations than to landlocked ones. The African country of Upper Volta, for instance, covers an area almost equal to that of the circle drawn about the Swan Islands, yet Upper Volta with nearly six million people would not have any oceanic fishing rights while the twenty-two Swan Islanders would enjoy rights to 126,000 square miles. Is this just?

There are many landlocked nations, and most of them are in Africa: Mali, Niger, Chad, Central African Republic, Uganda, Rwanda, Burundi, Malawi, Zambia, Rhodesia, Botswana, Swaziland and Lesotho. Landlocked nations are among the world's poorest. Is it just that their populations should be deprived of fishing rights?

Most of us would agree on the injustice of this possibility; nevertheless, let us explore its consequences. Imagine an ideal world of no nations and no national boundaries, a world in which people act merely as individuals or at most as small self-responsible communes. In such a world, would one argue that people living in the interior of a continent, perhaps a thousand miles from the ocean, have a right to as much seafood as people dwelling on a shore? The answer depends strongly on energy. It takes energy to grow or catch food; energy to transport food, marine or other, and to process and

store it. The farther the transport the greater the energy cost. Our future appears to be one in which energy will become ever more precious. Inlanders can enjoy an amount of seafood equal to that of shore dwellers only if they use a disproportionately large amount of energy to transport it. A just system can be interpreted either as equal distribution of the end product—food—or equal distribution of the means of getting food to people—energy. If the former definition is accepted, the per capita income of people is lowered because of the inefficient use of energy. Accepting the second definition increases per capita income, but results in differences in diets: inlanders will eat more grain; coastal people more fish. Whether this is an equitable system is debatable.

That the landlocked people of Lesotho cannot easily enjoy the delights of soft-shell clams is no special hardship. Similarly, people in Miami cannot easily enjoy skiing or people in the Yukon the delights of tropical fruits, unless transportation—an energy expenditure—is involved. End-product equality can be achieved only at the expense of efficiency, a cost that will be acceptable only at a high level of income. To put it bluntly, equality is a luxury that only the wealthy can afford. This is not the case, however, worldwide. Energy is scarce. If it is never more abundant than it is now, it seems unlikely that people will accept the inefficiencies of a more equal distribution of the oceans' wealth than now exists.

If we have the interests of posterity in mind, our most crucial need with respect to the biotic wealth of the ocean is to see to it that we adopt a politico-economic system that will make it possible for future generations to live at least as well as we do. The national property system embodied in the 200-mile limit may solve a few of our marine problems, but most of them will require some other departure from the system of the commons prevailing in the open ocean. This must take the form of an international organization with supranational sovereignty in fisheries control. The crucial question is, can we find a way to create this needed organization in time?

Garrett Hardin teaches human ecology at the University of California at Santa Barbara and is the author of numerous essays on the commons.

The Interpretation of Diagrams

Is the Cambrian "explosion" a sigmoid fraud?

Roderick Murchison, urged on by his wife, gave up the joys of fox hunting for the more sublime pleasures of scientific research. This aristocratic geologist devoted much of his second career to documenting the early history of life. He discovered that the first stocking of the oceans did not occur gradually with the successive addition of ever more complex forms of life. Instead, most major groups seemed to arise simultaneously at what geologists now call the base of the Cambrian period some 600 million years ago. To Murchison, a devout creationist writing in the 1830s, this episode could only represent God's initial decision to populate the earth.

Charles Darwin viewed this observation with trepidation. He assumed, as evolution demanded, that the seas had "swarmed with living creatures" before the Cambrian period. To explain the absence of fossils in the earlier geologic record, he apologetically speculated that our modern continents accumulated no sediments during Precambrian times because they were areas of clear seas.

Our modern view synthesizes these two opinions. Darwin, of course, has been vindicated in his cardinal contention: Cambrian life did arise from organic antecedents, not from the hand of God. But Murchison's basic observation reflects a biological reality, not the imperfections of geologic evidence: the Precambrian fossil record is little more (save at its very end) than 2.5 billion years of bacteria and blue-green algae. Complex life did arise with startling speed near the base of the Cambrian. (Readers must remember that geologists have a peculiar view of rapidity. By vernacular standards, it is a slow fuse indeed that burns for 10 million years. Still, 10 million years is but 1/450 of the earth's history, a mere instant to a geologist.)

Paleontologists have spent a largely fruitless century trying to explain this Cambrian "explosion"—the steep rise in diversity during the first 10 to 20 million years of the Cambrian period. They have assumed, universally, that the puzzling event is the explosion itself. Any adequate theory, therefore, would have to explain why the early Cambrian was such an unusual time: perhaps it represents the first accumulation of sufficient atmospheric oxygen for respiration or the cooling down of an earth previously too hot to support complex life (simple algae survive at much higher temperatures than complex animals) or a change in oceanic chemistry permitting the deposition of calcium carbonate to clothe previously soft-bodied animals with preservable skeletons.

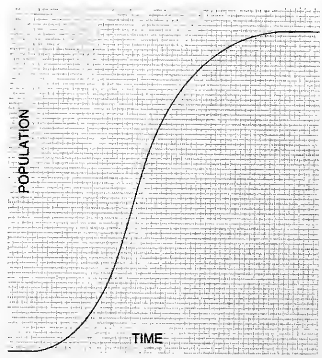
Perhaps paleontologists have been looking at this important problem the wrong way round. Perhaps the explosion itself was the predictable outcome of a process set in motion by an event earlier in the Precambrian. In such a case, we would not have to believe that early Cambrian times were "special" in any way; the cause of the explosion would be sought in an earlier event that initiated the evolution of complex life. I have recently been persuaded that this new perspective is probably correct. The pattern of the Cambrian explosion seems to follow a general law of growth. This law predicts a phase of steep acceleration; the explosion is no more fundamental (or in need of special explanation) than its antecedent period of slower growth or its subsequent leveling off. Whatever initiated the antecedent period virtually guaranteed the later explosion. In support of this new perspective, I offer two arguments based on a quantification of the fossil record. I hope not only to make my particular case but also to illustrate the role that quantification can play in testing hypotheses within professions that once eschewed such rigor.

The day-to-day work of field geology is a painstaking exercise in the accumulation of apparent minutiae: the mapping of strata; their temporal correlation by fossils and by physical "superposition" (younger above older); the recording of rock types, grain sizes, and environments of deposition. This activity is often poohpoohed by hot-shot young theorists who regard it as the dog work of unimaginative drones.

Yet we would have no science without the foundation that these data provide; moreover, many theoretical advances depend upon new data accumulated in the old way. In this case, our revised perspective on the Cambrian explosion rests upon a refinement of early Cambrian stratigraphy established primarily by Soviet geologists in recent years. The long Lower Cambrian has been subdivided into four stages and the first appear-

ances of Cambrian fossils have been recorded with much greater accuracy. We can now tabulate a finely divided sequence of first appearances where previous stratigraphers could only record "Lower Cambrian" for all groups (thus accentuating the apparent explosion).

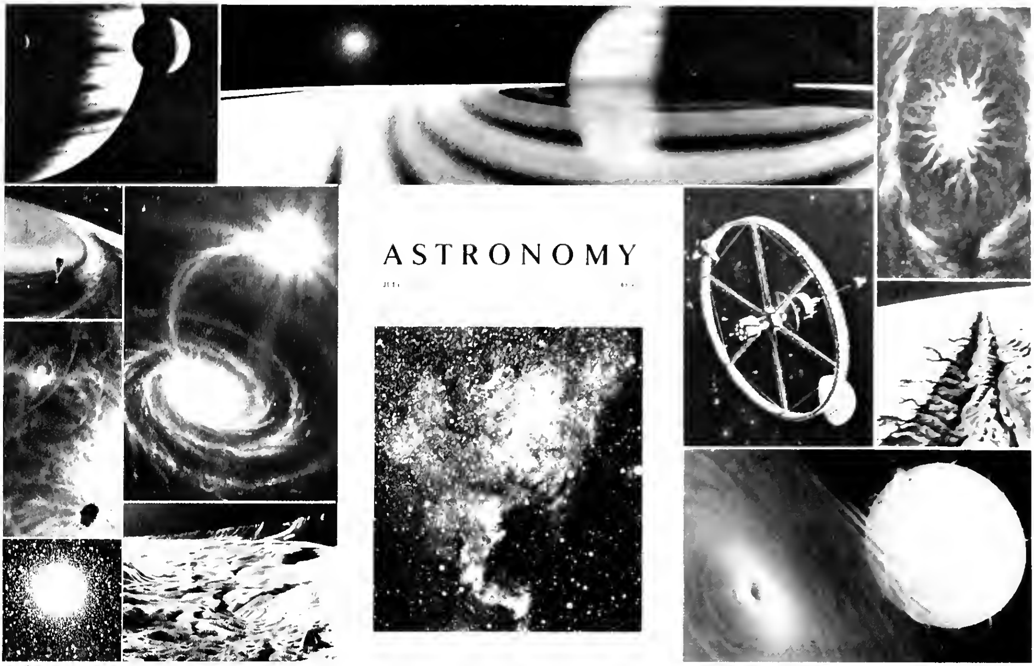
J.J. Sepkoski, a paleontologist at the University of Rochester, has recently found that a plot of increasing organic diversity versus time from the late Precambrian to the end of the "explosion" conforms to our most general model of growth—the so-called sigmoidal (S-shaped) curve. Consider the growth of a typical bacterial colony on a previously uninhabited medium: each cell divides every twenty minutes to form two daughters. Increase in population size is slow at first. (Rates of cell division are as fast as they will ever be, but



founding cells are few in number and the population builds slowly toward its explosive period.) This "lag" phase forms the initial, slowly rising segment of the sigmoidal curve. The explosive, or "log," phase follows as each cell of a substantial population produces two fecund daughters every twenty minutes. Clearly this process cannot continue indefinitely: a not-too-distant extrapolation would fill the entire universe with bacteria. Eventually, the colony guarantees its own stability (or demise) by filling its space, exhausting its nutrients, fouling its nest with waste products, and so on. This leveling puts a ceiling on the log phase and completes the S of the sigmoidal distribution.

It is a long step from bacteria to the evolution of life, but sigmoidal growth is a general property of certain systems, and the analogy seems to hold in this case. For cell division, read speciation; for the agar substrate of a laboratory dish, read the oceans.

Man's Dream of Worlds Unseen



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The lag phase of life is the slow, initial rise of latest Precambrian times. We now have a modest fauna of the latest Precambrian age—mainly coelenterates (soft corals and jellyfish) and worms. The famous Cambrian explosion is nothing more than the log phase of this continuous process, while post-Cambrian leveling represents the initial filling of ecological roles in the world's oceans (terrestrial life evolved later).

If the laws of sigmoidal growth regulated the early diversification of life, then there is nothing special about the Cambrian explosion. It is merely the log phase of a process determined by two factors: (1) the event that initiated the lag phase well within Precambrian times and (2) the properties of an environment that permitted sigmoidal growth.

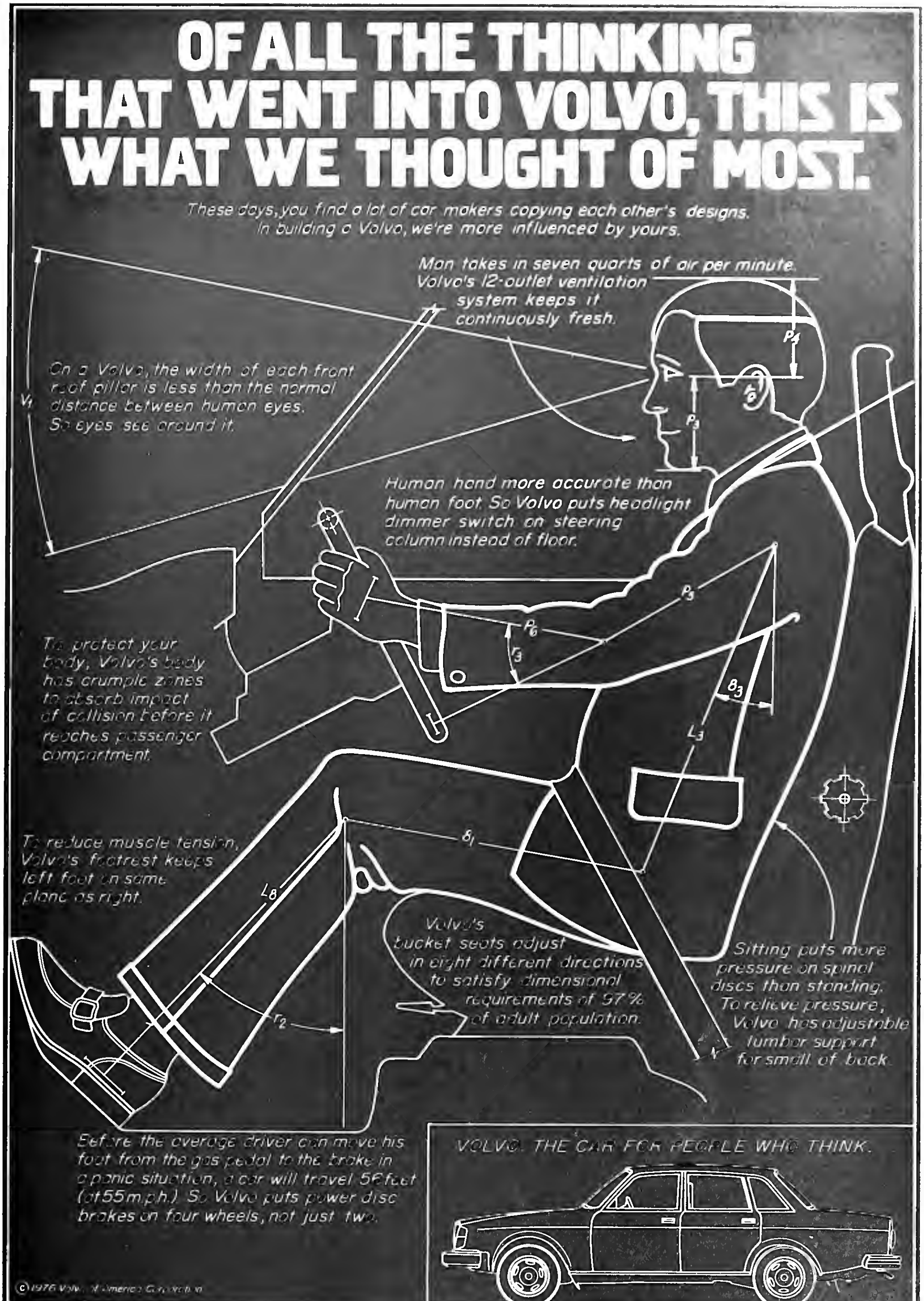
As Johns Hopkins paleontologist S. M. Stanley wrote in a recent review (*American Journal of Science*, 1976): "We can abandon the traditional view that the origins of major fossil taxa near the start of the Cambrian . . . represent a major enigma. What remains as the 'Cambrian Problem' is the delay of the origin of multicellularity until the Earth was nearly 4 billion years old." We may deny the Cambrian problem by casting it back upon an earlier event, but the nature and cause of this earlier episode is the enigma of paleontological enigmas. The late Precambrian origin of the eukaryotic cell must provide an important determinant. (I argued in my last column that efficient sexual reproduction required a eukaryotic cell with discrete chromosomes, and that complex organisms could not evolve without the genetic variability that sexual reproduction supplies.) But we haven't the slightest idea why the eukaryotic cell arose when it did more than 2 billion years after the evolution of prokaryotic ancestors; we do not even know how it arose. (I have supported the idea that it developed as a colony of prokaryotic organisms and that the nuclei and mitochondria of our cells were once entire prokaryotic creatures—see my columns of November 1974 and June-July 1976.)

Previously I advocated Stanley's "cropping" theory for the initiation of sigmoidal increase following the evolution of eukaryotic cells. Stanley argues that Precambrian prokaryotic algae had usurped all available space in their potential habitat, thus precluding the evolution of anything

more complex by denying a foothold to any competitor. The first eukaryotic herbivore, in the course of its copious, if unvaried, worldwide feast, freed enough space for the evolution of competitors.

Speculation may be intriguing, but we have little concrete to say about my first factor—the cause that initiated sigmoidal increase. We can, however, do better for the second—the nature of an environment that permitted it. Sigmoidal growth is not a universal property of natural systems; it occurs only in one kind of environment. Our laboratory bacteria would not have increased in an S-shaped curve if their culture plate was already densely populated or devoid of nutrients. Sigmoidal patterns occur only in open, unconstrained systems, where food and space are so abundant that organisms grow until their own numbers limit further increase. The Precambrian oceans clearly formed such an "empty" ecosystem—plenty of space, abundant food, no competition. (The early eukaryotes could thank their prokaryotic ancestors not only for an immediate supply of food but also for their prior service in supplying oxygen to the atmosphere through photosynthesis.) The sigmoidal curve—with the Cambrian explosion as its log phase—represents the first stocking of the world's oceans, a predictable pattern of evolution in open ecosystems.

Animals evolving during the log phase should show different evolutionary patterns from those arising later in a regime of self-regulated equilibrium. Much of my own research in the past two years has been devoted to defining these differences. My colleagues (T.J.M. Schopf of the University of Chicago, D.M. Raup and J.J. Sepkoski of the University of Rochester, and D.S. Simberloff of Florida State University) and I have been modeling evolutionary trees as a random process. After "growing" a tree, we divide it into its major "limbs" and consider the history of each limb (technically called a "clade") through time. We depict each clade as a so-called Mae West diagram (pardon the sexism of a profession still overwhelmingly male—but the diagrams often wax and wane in a very curvaceous fashion, and none of us invented the term anyway). Mae West diagrams are constructed in the following way: Simply count the number of species living during each period of time and vary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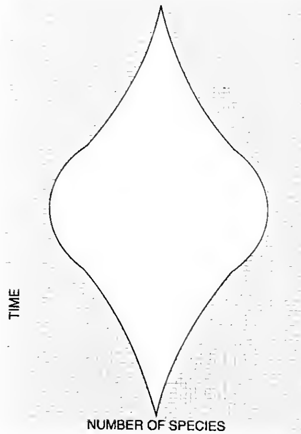
the width of the diagram according to this number.

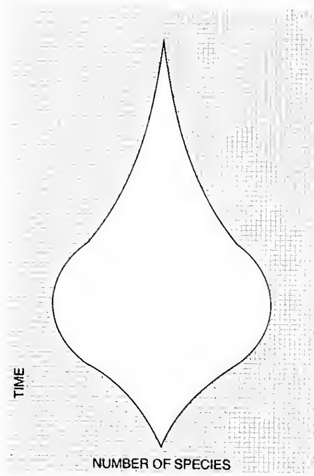
We then measure several properties of these diagrams. One measure, called C.G., defines the position of the center of gravity (roughly, the place where the clade is widest, or most diverse). If this position of maximum diversity occurs at the midpoint of the clade's duration, we give C.G.



a value of 0.5 (halfway in the clade's total existence). If a clade reaches its greatest diversity before its midpoint, it has a C.G. of less than 0.5.

In our random system, C.G. is always near 0.5—the ideal clade is a diamond widest at its center. But our random world is one of perfect equilibrium. No log phases of sigmoidal growth are permitted; a constant number of species is maintained through time, as rates of extinction match rates of origination.

I spent a good part of last year counting fossil genera and recording their longevity in order to construct Mae West diagrams for real clades. I now have more than 400 clades for groups that arose and died *following* the log phase of the Cambrian explosion. Their mean value is 0.4993—couldn't ask for anything closer to the 0.5 of our idealized world at equilibrium. I also have as many Mae West diagrams for clades that arose *during* the log phase and died out afterward. Their mean C.G. is significantly less than 0.5. They record an atypical world of increasing diversity, and their values can be used to assess both the timing and the strength of the Cambrian log phase. Their values are below 0.5 because they arose during times of rapid diversification. But they died out during stable times of



slower origin and extinction. Thus, they reached their maximum diversity early in their history since their first representatives participated in a log phase of unrestrained increase, but petered out more slowly during the stabilized world that followed.

A quantitative approach has helped us to understand the Cambrian explosion in two ways. First, we can recognize its character of sigmoidal growth and identify its cause in an earlier event; the Cambrian problem, per se, disappears. Secondly, we can define the time and intensity of the Cambrian log phase by studying the statistics of Mae West diagrams.

To my mind, the most remarkable result of this exercise is not the low C.G. of Cambrian clades, but the correspondence of C.G. for later clades to an idealized model for a world at equilibrium. Could it be that the diversity of life has remained at equilibrium through all the vicissitudes of an earth in motion, all the mass extinctions, the collision of continents, the swallowing up and creation of oceans? The log phase of the Cambrian filled up the earth's oceans. Since then, evolution has produced endless variation on a limited set of basic designs. Marine life has been copious in its variety, ingenious in its adaptation, and (if I may be permitted an anthropocentric comment) wondrous in its beauty. Yet, in an important sense, things have been pretty quiet since the Cambrian—and so they are likely to remain.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.


Steve Crouch

Currents of the Sea

by W. Redwood Wright

Propelled by winds, solar heat, and the rotation of the earth, the ocean water moves in chartable patterns

The world's seven seas are really one global ocean surrounding the continental land masses. The three great ocean basins—the Atlantic, the Pacific, and the Indian—are joined at their southern extremities by the Southern Ocean whose waters encircle Antarctica. The ocean basins are connected by currents that flow horizontally from one region to another and up and down between the surface and the depths. Movement at the surface is relatively rapid. The deep movement is very slow, with a time scale of centuries, but the amounts of water involved are massive.

Like almost everything that moves on the face of the earth, the major currents of the world ocean are ultimately driven by energy from the sun. (Coastal currents, which have a strong tidal component, are not considered here.) Solar energy affects the ocean in two major ways—directly, through solar radiation, and indirectly, through the winds. Because the earth rotates from west to east and because its surface is unevenly heated by the sun, there is a global wind system that consists basically of easterlies, or trade winds, that extend from the subtropics to the equator; westerlies at the mid-latitudes; and easterlies again at the high latitudes.

The winds blowing over the ocean transfer some of their energy to the sea surface; most of it goes into making waves, but a fraction, perhaps 10 percent, imparts to the surface layers a motion deflected at a slight angle to the direction of the wind—to the right in the Northern Hemisphere and to the left south of the equator. (Winds are designated by the direction from which they come; water flow is described by the direction in which it is moving.) There is thus a westward flow of water in equatorial regions and an easterly flow in the mid-latitudes, with some tendency for accumulation in between.

Unlike the atmosphere, however, the oceans have the barriers of the continents; only in the Southern Ocean can the West Wind Drift, also known as the Antarctic Circumpolar Current, continue uninterrupted around the globe. Elsewhere the zonal (westward and eastward) motions of the water combine with meridional (poleward and equatorward) flows to form huge rings, or gyres, of current. The most extensive of these are the subtropical gyres, which flow clockwise in the Northern Hemisphere and counterclockwise in the Southern. In the North Pacific and the North Atlantic and apparently in the Weddell Sea of Antarctica there are subpolar gyres that flow in the opposite direction. Again because of the earth's rotation, the meridional flows on the west sides of oceans tend to be relatively narrow, strong currents, while those on the east sides are broader, more diffuse, and slower, and therefore less amenable to observation.

In considering this flow system, the direct effects of solar radiation must also be taken into account. Radiation is stronger at the equator than at the poles. The resultant temperature and salinity differences affect the density of the sea surface. Water contracts as it cools and hence becomes more dense; salt also increases density. Normally the changes in temperature and salinity counteract each other:

tropical warming makes water less dense but also increases evaporation and hence salinity, and that, in turn, makes the water denser. In polar regions the reverse occurs, with cooling opposed by an excess of precipitation over evaporation. The difference between the densest water, for example, that flowing out of the Mediterranean, and the least dense, such as at the tropical sea surface, is less than 0.5 percent, but it is very important.

The ocean is vertically stable nearly everywhere; that is, the deeper water is denser than the water directly above it, but there are horizontal differences in density. In the subtropical gyres, a lens of lighter water "floats" on the denser water around it; its surface is actually as much as three feet higher. Polar water tends to sink and move toward the equator along sloping surfaces of constant density. As a result of these differences, there are horizontal pressure gradients that are balanced by horizontal currents, just as atmospheric pressure gradients are accompanied by currents of air. The combination of vertical and horizontal motions established in this manner is known as the thermohaline circulation. It is most important in the deeper layers of the sea but is also significant in the upper ocean.

Although it is convenient to separate circulation into surface and deep systems, the distinction is not so clear-cut in reality. Some of the major surface currents, such as the Gulf Stream and the Antarctic Circumpolar Current, have been found to extend all the way to the bottom, and most of the so-called deep currents originate at the sea surface in high latitudes. In fact, there is a small vertical component to most, perhaps all, flows in the ocean, with sinking in a few localized regions and rising elsewhere, so that the whole system is eventually turned over.

The existence of surface currents has been known and used to advantage by mariners since the earliest navigators ventured offshore. In the tenth century, dhow skippers in the Arabian Sea knew that the currents, as well as the winds, changed direction with the monsoons; Polynesian voyagers knew how to play the currents and countercurrents of the Equatorial system; and within a few years of the voyages of Columbus, the Spanish treasure fleets were riding home from the New World with a boost from the Gulf Stream. Even today's gigantic but relatively slow tankers seek out routes that will enable them to benefit from the current or avoid a contrary flow, and Bermuda-bound yachtsmen plot the temperature of the sea surface as a guide to making the best use of Gulf Stream meanders.

Knowledge of the deep circulation, however, goes back little more than a century, to the development of thermometers that could record deep temperatures and retain the reading while being hauled up through the surface layers. During the celebrated cruise of H.M.S. *Challenger* (1872–76), a worldwide series of deep temperature measurements demonstrated that, regardless of the temperature at the sea surface, deep water everywhere is cold. It was noted, however, that the deep temperatures in all the major ocean basins increased toward the north, away from the Antarctic. The *Challenger* data indicated to contemporary scientists that there must be a slow northward flow from the Antarctic into the world oceans, a view that has been sustained with minor modifications ever since.

At the turn of the century, the polar explorer Fridtjof Nansen speculated on the basis of some deep northern observations that the Norwegian Sea is a source of deep water for the abyssal circulation. His idea, unfortunately neglected for nearly half a century, was not revived until the 1950s. The contribution of the Mediterranean Sea to deep ocean circulation was understood, at least in concept, by a Victorian physician-naturalist who tried to measure the subsurface outflow at Gibraltar by lowering a cannonball below his dinghy.

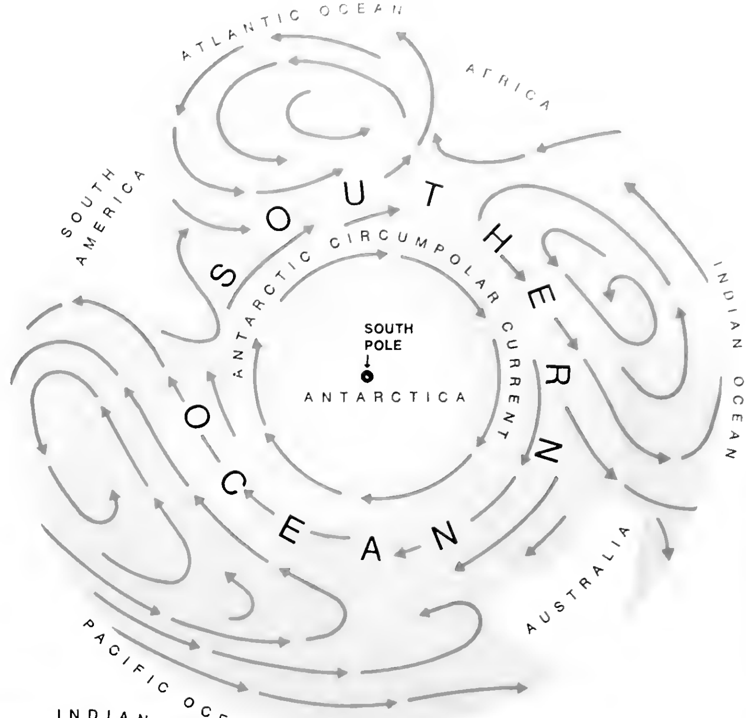
Such crude methods of direct current measurement were all that was possible until electronic techniques were introduced during and after World War II. Oceanographers had to rely primarily upon indirect means, inferences based upon widespread spot observations of temperature, salinity, and other variables, and the mapping of their distribution. In the deep ocean such observations take time—at best, three to four hours per station—distances between stations are large and research vessels are usually small, so that data accumulation was very slow. As recently as 1960 the circulation in the Pacific Ocean below 16,000 feet was described on the basis of only 145 stations, each one representing on average an area half again as large as Texas. (There are now about 600 such stations in the Pacific—for Texas, read New Mexico.)

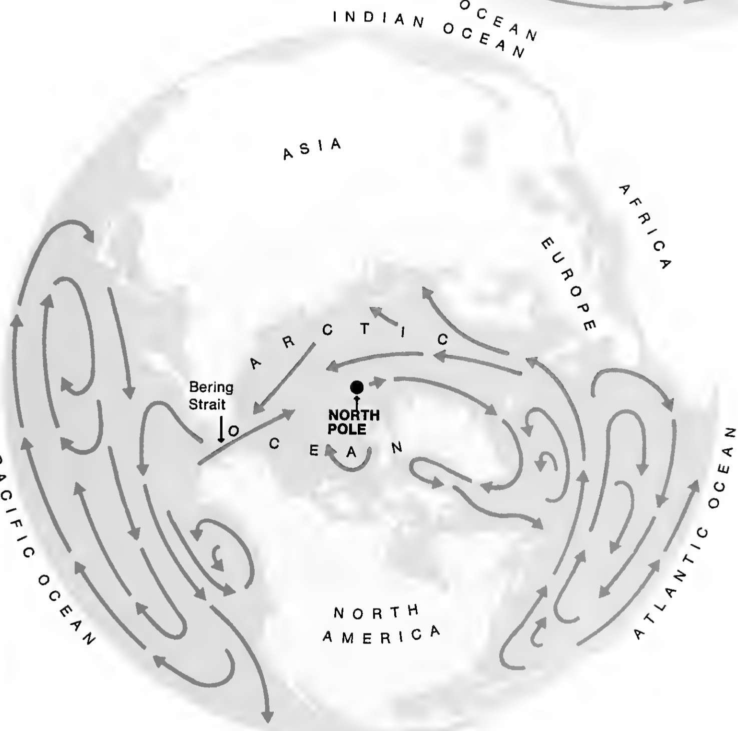
In addition to analysis of distribution patterns, it was possible to calculate the speed and volume transport of a current by resolving the "geostrophic" equation, a simplified balance of forces that relates the distribution of pressure in the ocean to the deflecting effect of the earth's rotation. However, the reliability of the calculation was—and still is—severely hampered by the need for some absolute reference point.

The wartime development of loran, a radio navigation system, made possible frequent and precise position fixing, so that ship drift could be determined with reasonable accuracy. Two other new developments were the bathythermograph, a diving thermometer that records temperatures in the upper layers from a moving ship, and the geomagnetic electrokinetograph, or GEK, which senses currents by measuring the electrical potential set up by the motion of a conductor (seawater) through a magnetic field (the earth's). With these devices it was possible to describe some of the fluctuations of surface currents. It then became apparent that for most of its length the Gulf Stream is not a "river in the ocean" confined to a single path, as described by Matthew Fontaine Maury, the nineteenth-century U.S. naval officer who made the first worldwide wind and current charts, but rather a highly variable flow with huge meanders propagating downstream so that the position, speed, and direction of flow are constantly changing.

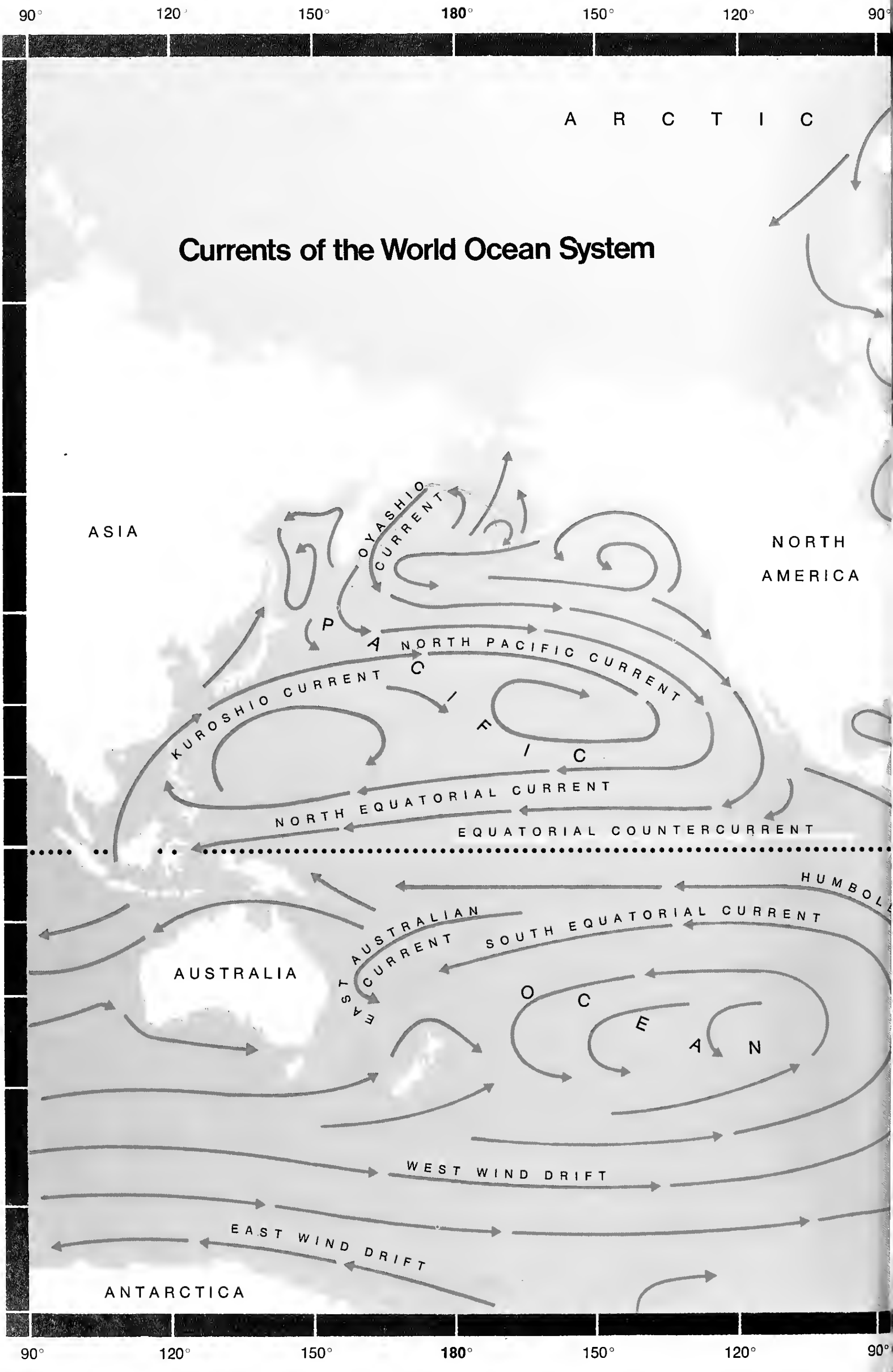
In the 1950s a tenfold increase in the accuracy of salinity measurements was achieved when chemical titration was replaced by machines based on electrical conductivity. With these new instruments, fine differences between water masses could be identified and another era of investigating the deep ocean was inaugurated.

The interconnectedness of the world's oceans is apparent when the earth is viewed from the poles. The Southern Ocean, which surrounds Antarctica, links the Atlantic, Pacific, and Indian basins. The Antarctic Circumpolar Current in the Southern Ocean (also known as the West Wind Drift) is perhaps the most important of the major ocean currents. It is the only one that flows around the globe unimpeded by any land masses.





The Arctic Ocean, a marginal sea of the Atlantic, is connected to the Pacific by the Bering Strait. Shallow and narrow, the strait permits only a relative trickle of water to flow over its sill. Nevertheless, it is enough to help maintain the fundamental unity of the global ocean.



Currents of the World Ocean System
ARCTIC
ASIA
NORTH AMERICA
OYASHIO CURRENT
PACIFIC OCEAN
NORTH PACIFIC CURRENT
KUROSHIO CURRENT
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTERCURRENT
HUMBOL
SOUTH EQUATORIAL CURRENT
EAST AUSTRALIAN CURRENT
AUSTRALIA
WEST WIND DRIFT
EAST WIND DRIFT
ANTARCTICA
90°
120°
150°
180°
150°
120°
90°
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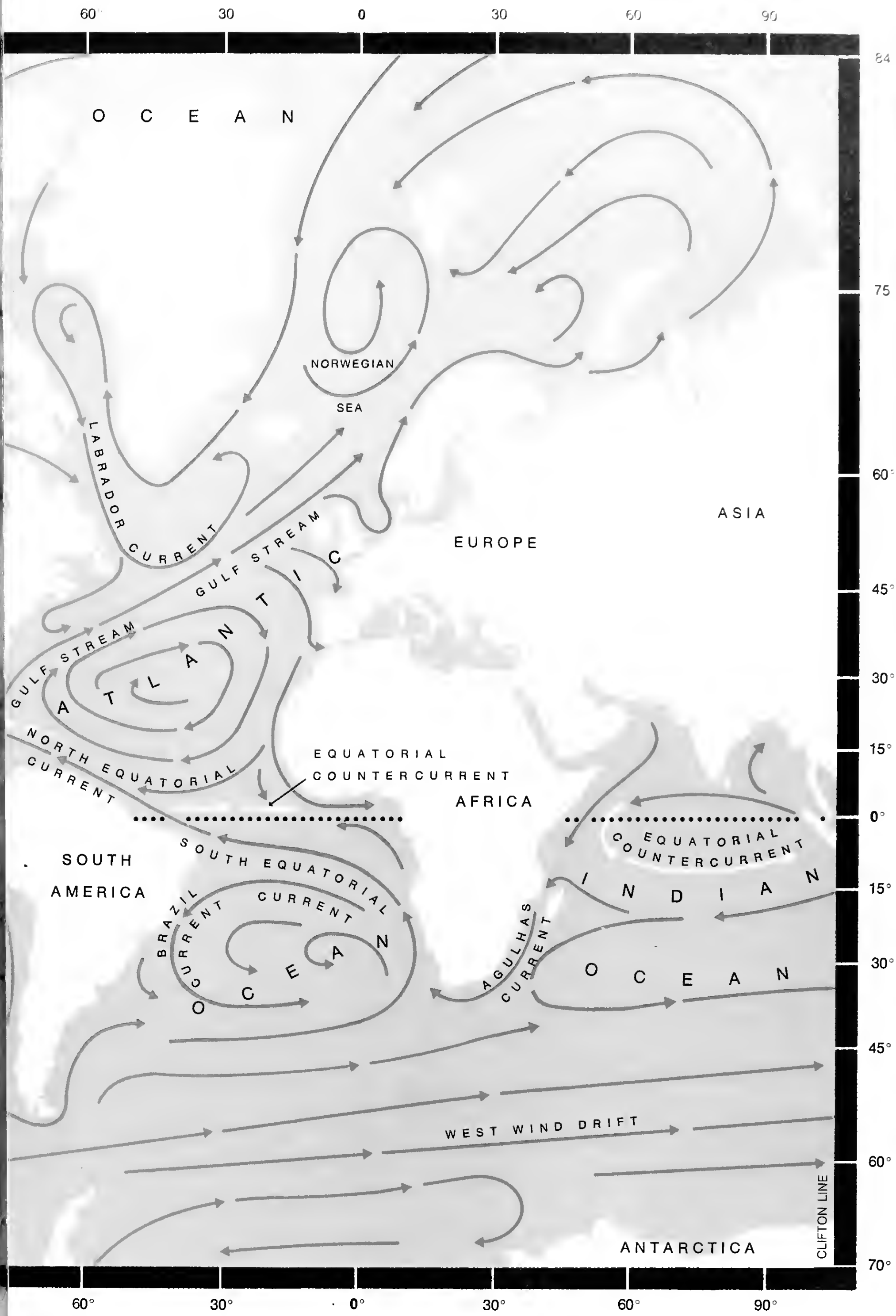

OCEAN
NORWEGIAN SEA
LABRADOR CURRENT
GULF STREAM
ATLANTIC
EUROPE
ASIA
NORTH EQUATORIAL CURRENT
EQUATORIAL COUNTERCURRENT
AFRICA
SOUTH AMERICA
SOUTH EQUATORIAL CURRENT
BRAZIL CURRENT
OCEAN
AGULHAS CURRENT
EQUATORIAL COUNTERCURRENT
INDIAN OCEAN
WEST WIND DRIFT
ANTARCTICA
CLIFTON LINE
60
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60°
90°

Direct current measurements in deep water have taken two forms: anchored meters that measure the speed and direction of the water flowing past them, and free instruments that descend to a predetermined depth and move along with the flow. Both techniques are time-consuming and expensive—a single mooring with several current meters and a release to drop the anchor on command can cost more than $100,000—and such observations have consequently been made in only a few places in the world ocean.

The first lesson learned from the new instruments was that the motion in the deep ocean was not a broad, slow flow, as had generally been imagined, but covered a whole spectrum of time and space scales that may be at least as complicated as the surface circulation. This discovery has opened up several new fields of investigation into the small- and medium-scale motions, but it is not yet clear how these aspects of oceanic movement relate to the general circulation. It also means that short-term measurements in any one place do not tell much about what is going on.

Probably the largest of all ocean currents is the Antarctic Circumpolar Current, or West Wind Drift, which flows eastward around Antarctica. It is separated from the continent by the East Wind Drift, a much smaller coastal current set up by the predominant easterlies of the polar land mass.

The Circumpolar Current is very cold at the surface, often less than 0°C near its southern limits. It is also rich in nutrients and thus full of life, from tiny plankton to the largest remaining populations of the great whales; countless sea bird rookeries exist on the otherwise barren and inhospitable rocks and islets of the region. The current is not terribly swift—perhaps a knot at the surface and one-fifth of that in the depths—but it is both broad and deep and has been estimated to carry about 200 million tons of water past a given point each second. To put this figure in some kind of perspective, it is about 150 times the combined flow of all the world's rivers and would fill the Great Lakes in about two days but would require more than 100 years to fill the Pacific Ocean.

In each of the major oceans the Circumpolar Current is the southern limb of the subtropical gyre, which reaches to the equator via a northward-flowing, eastern boundary current and a swifter, southbound western boundary current. Because of their tropical origin, the western boundary currents—the Brazil Current in the South Atlantic, the Agulhas in the South Indian, and the East Australian in the South Pacific—are relatively warm and saline. The eastern boundary currents, in contrast, arise in high latitudes and tend to be colder, less salty, and richer in nutrients. Enhancing this condition, the winds on the east sides of oceans generally blow toward the equator. The surface waters are diverted offshore, to the left of the wind direction, and are replaced by upwelling deeper water that is also generally cold, fresh, and rich. The system supports some of the world's greatest fisheries, along with associated predators such as sea birds and humans.

Major fluctuations in eastern boundary currents can be disastrous. The region of the Humboldt (or Peru) Current, along the west coast of South America, produces about 20 percent of the world fish catch. Some years, apparently as a result of relaxation of the southeast trade winds and heavy equatorial rains, there is an incursion of abnormally warm surface water along the coast. Lacking nutrients, the entire food chain collapses. Fish die, sea birds go elsewhere, and Peruvian fishermen become impoverished. The condition is known as El Niño ("the child") because it has usually occurred at Christmastime. Fishery scientists now believe they can predict the severity of El Niño by measuring upper air winds over the equatorial Pacific.

The classic picture of the Equatorial Current System consists of two westward flows, the North and South Equatorial currents, which are driven respectively by the northeast and southeast trades, and are separated by the doldrums and an eastward-flowing countercurrent. But the system is not that simple. The currents vary seasonally in position and strength and may disappear on occasion. The most consistent of the three flows, the South Equatorial Current, is strongest in northern summer; the opposite is true of the North Equatorial Current, which actually reverses with the monsoon in the Indian Ocean. There is, in addition, recent evidence of a South Equatorial Countercurrent flowing eastward in the Pacific at about 5° to 10° south latitude.

One of the real surprises of modern oceanography was the discovery of a thin ribbon of water flowing rapidly eastward directly along the equator and only about 300 feet below the westbound South Equatorial Current at the sea surface. This Equatorial Undercurrent extends about two degrees north and south of the equator and is only about 600 feet thick. It carries a core of high salinity water. This unexpected feature was discovered during a long-line fishing expedition in the Pacific Ocean in the late 1950s. The countercurrent was subsequently found to be a worldwide feature with Atlantic and Indian Ocean counterparts, but much remains to be learned about its origin and fate and why it is there at all.

The strongest western boundary currents—the Gulf Stream in the Atlantic and the Kuroshio in the Pacific—are found north of the equator. The Kuroshio carries warm and saline water past the islands of Japan. Its extension crosses the Pacific at about 40° north latitude and divides at the North American coast; part flows south along the California coast, where it is considered cold, and part flows north past Canada and Alaska, where it is considered warm. The Oyashio, a cold southward current along the Asian continent, may be part of the return flow. The Kuroshio fluctuates in position and speed and its movements are important to the fishermen of Japan.

The Gulf Stream originates with source waters that flow into the eastern Caribbean Sea. The stream flows northward past Yucatan, generally eastward through the Gulf of Mexico past Cuba, and northward again through the Straits of Florida and up the east coast to Cape Hatteras. Up to this point it is still less than 3,000 feet deep, often faster, but not appreciably more powerful, than other major currents, and its path has only minor fluctuations. Beyond Hatteras all this changes—the coast turns almost due north but the current continues to the northeast, moving offshore where it incorporates the under-

lying deep water. Its transport doubles to about 150 million tons per second, and its speed can be measured all the way to the bottom. At the same time its path becomes more erratic, and great meanders develop north and south of the mean path. Occasionally these meanders pinch off to form rotating rings of water 50 to 100 miles in diameter that persist as independent entities for months or years before they dissipate or are reabsorbed into the stream. Infrared satellite photography, which reveals sea surface temperature contrasts, has helped to map these patterns; there now appear to be about six such rings formed each year on each side of the Gulf Stream.

East of Cape Cod the stream diminishes and off the Grand Banks of Newfoundland it is back to its Hatteras size. North and east of the Banks the picture is less clear. There is a cold, fresh, relatively shallow and weak flow, the Labrador Current, running southward along the Canadian coast. There is also a flow of warm water that ultimately bathes northern Europe so that palm trees grow in Cornwall at the latitude of Newfoundland and even the southern harbors of Iceland are usually ice-free and open for shipping year-round. This flow is generally thought to be an extension of the Gulf Stream, but there is persuasive evidence that east of the Grand Banks the major part of the stream turns south and recurves to the west. The flow that warms Europe may come from the eastern Atlantic off North Africa rather than from the Gulf Stream. Whatever its origin, there is warm and saline Atlantic surface water flowing into the Norwegian Sea, and thus begins the tale of the deep circulation.

There are only two places in the world ocean where significant quantities of bottom water are known to be produced, that is, where atmospheric effects make surface water sufficiently dense to sink to the bottom. These are near the two poles. In the Norwegian Sea the effect is accomplished by winter cooling, so that a mass of cold and relatively saline water accumulates in the sea's deep basins. The Norwegian Sea is separated from the Atlantic Ocean by a sill 1,500 to 2,500 feet deep that extends from Greenland to Scotland by way of Iceland and the Faeroe Islands. The dense water overflows the ridge and cascades downslope into the deep Atlantic. "Cascade" may be too strong a word, as the speeds are little more than three knots, but the process is sufficiently turbulent to pick up a good deal of Atlantic water at intermediate depths. The mixture, known as North Atlantic Deep Water, is produced in quantities that are small compared with the transport of the great surface currents, perhaps ten million tons per second, and whether the flow is sporadic or continuous is not known.

The other bottom water source is the icebound Weddell Sea of the Antarctic. The Antarctic Bottom Water produced there is less saline, but colder and therefore denser, than North Atlantic Deep Water; it is distributed around Antarctica and into the ocean basins by the Circumpolar Current. Given the place and the season, production of Antarctic Bottom Water is not an easy process to observe, and there is some debate about how regular it is or even if it is now taking place at all. But there is no doubt about its long-term importance, for Antarctic Bottom Water constitutes more than half the water in the world ocean. It fills the deep regions of the Indian and Pacific oceans and the South Atlantic and is found under the North Atlantic Deep Water as far away as the latitude of Bermuda.

Elsewhere, surface effects produce less dense water masses that circulate at intermediate depths above the deep and bottom water. Antarctic Intermediate Water is formed by the convergence of warmer, saline, subtropical water with the chill Circumpolar Current; it flows northward at a depth of about 3,000 feet in all the oceans, distinguished by a salinity minimum.

In the North Atlantic between Newfoundland and Greenland, winter cooling forms another, relatively fresh water mass, which occupies the northern part of the basin at about 5,000 feet. In the Mediterranean the governing mechanism is evaporation, which fills the deep basin with warm but very saline, dense water. It flows out across the sill at Gibraltar, much as the North Atlantic Deep Water escapes the Norwegian Sea, mixes rapidly with the Atlantic water outside, and spreads across the ocean as a saline tongue centered at about 4,000 feet.

The flow of the deepest water masses is restricted by bottom topography, principally by the mid-oceanic ridges. Thus, Antarctic Bottom Water is not found in the eastern basin of the Atlantic north of about 20° south; it is cut off by the Walvis Ridge that rises some 6,000 feet above the sea floor between the Mid-Atlantic Ridge and the coast of South-West Africa. The coldest North Atlantic Deep Water is similarly restricted by the Mid-Atlantic Ridge to the western basin of the ocean.

Until recently, the deep-water motion was imagined to be a broad and sluggish creep, distributed more or less uniformly across entire ocean basins. This simple picture has been upset by a combination of careful observation and bold theory. The theory is based on the requirement of a slow upward motion in the oceanic interior to balance the downward flow of "new" bottom water. Combining this upward movement with the effects of rotation produced the surprising result that the deep flow over most of the ocean should move toward the source at the poles. Such a flow can only be supplied by relatively swift, narrow, deep equatorward western boundary currents.

The deep western boundary currents are the only part of the theory currently amenable to testing in the ocean. In the North Atlantic such a current has been found along the North American continental slope; it flows under the Gulf Stream at Cape Hatteras and has been traced as far as the deep water north of Puerto Rico. In the western South Atlantic and South Pacific, deep equatorward currents have also been identified. The one in the South Pacific is characterized in part by a slight, but measurable, salinity maximum that can be traced back to its source in the northern North Atlantic—a subtle indication of the fundamental unity of the oceans. Much of the theory remains to be verified; there are tantalizing inconsistencies and surely more surprises in store, but what is known feeds the hope that a genuine understanding of the global ocean circulation may soon be within reach. □

Deep-Sea Fishes

Text and photographs by Bruce H. Robison

Beneath the reach of sunlight, bizarre predators stalk, lure, and ambush their prey

In the cold, dark waters of the deep sea, the process of evolution has encountered a set of harsh and challenging environmental conditions. Sunlight seldom reaches depths of more than 2,000 feet, while the average depth to the bottom of the world's oceans is about 13,000 feet. This means that at least 85 percent of the marine environment is in continual darkness. Temperature decreases rapidly with depth; from 20°C or more in the wind-mixed surface layer to 5° or 6°C at 3,300 feet. In some oceans the water column contains a zone of low oxygen content. Few places on our planet offer a more inhospitable environment than the vast, dark waters of the deep sea, where supply lines must stretch upward for thousands of feet to the surface. Despite these conditions, the deep waters below the open oceans have been colonized by an array of highly specialized animals.

The deep-sea environment exists out beyond the margins of continental shelves. The animals that live there, away from the bottom and not wholly near the surface, are called midwater animals. Their free-swimming lifestyle is termed "pelagic" by oceanographers, and the oceanic water column in which they live can be divided into zones of characteristic conditions. The epipelagic zone is the upper, productive layer; the mesopelagic is the dimly lit transition zone between about 650 and 3,300 feet; and the bathypelagic is the deep, dark zone below 3,300 feet.

Most of the creatures that now inhabit the deep sea probably evolved from near-surface forms. Their ancient predecessors left the warm, sunlit, and productive upper layers because of competition from an increasing variety of shallow-water species and because of what I consider to be the intrinsic drive that compels the flow of life forms into every attainable living space on the planet.

For the animals that entered this unexploited living space, it was advantageous to evolve special structures, physiological processes, and behavioral patterns as means of coping with the rigorous conditions. Their adaptations have resulted in some of the strangest and most interesting fishes in the sea.

The most abundant group of fishes in a deep-sea community are "nibblers." They feed on a multitude of tiny crustaceans, which "graze" on the phytoplankton of the sunlit surface waters. Most midwater animals shun the light of the sun, but at night many nibbler species swim upward to consume the crustaceans grazing in the rich upper layer. In the early morning, they return to darker, deeper water. The fishes that prey upon nibblers are also drawn upward at night, and the movements of all these animals contribute significantly to the cycling of nutrients into deeper water.

Myctophids, or lanternfish, are typical nibblers. This family has a worldwide distribution and constitutes a major dietary item for tuna and porpoises. They are called lanternfish because of the luminous organs patterned on their bodies. The characteristic arrangements of these organs are used by taxonomists to distinguish between species, and it is thought that the fish probably do this as well. Some of the patterns also denote sexual differences, while other organs may serve to illuminate the water as an aid in finding prey.

The myctophids are a diverse family of about 200 species; by studying the patterns of their diversity much can be learned about the factors that influence their lives. Coloration, matching the light levels of a species' depth range, is an easily illustrated example that also correlates somewhat with body composition, behavior, and ecological role. The deepest-living myctophids (3,300 feet, or so) are black; they do not attempt long, upward feeding migrations; and their bodies seem weak and flaccid. They depend on nutrients that are transported to great depths through biological systems. In contrast, shallow-water species are brightly silver, firm bodied, and commute regularly from their dim daytime depths (950–1,300 feet) to the surface at night to feed. Between these extremes of color and depth range are myctophids with intermediate characteristics and different ecological roles.

Other fishes and crustaceans share the deep-sea living space with myctophids and compete with them for the same general food resources. Among them are fishes of the genus *Cyclothone,* the most numerous vertebrates on earth. These are small, frail-looking fish that do not undertake daily, vertical feeding migrations; instead, they occupy relatively fixed horizons of depth. The various species of this genus that inhabit a common geographical area avoid direct competition with one another by partitioning the water column into separate depth ranges. The deeper-living species are black, protectively matched to the darkness of their environment, while the shallower species are translucent to blend with dim light. Related species include the robust fishes of the genus *Gonostoma,* which are vertically mobile, and the oddly shaped hatchetfish family, which are not. The nibblers are the largest ecological group of fish in the open ocean; a group that is itself a food resource that supports a broad array of predators at other levels of the oceanic food web.

Lurking in the blackness of the deep sea, a melanostomiatid probably lures prey toward its toothy jaws with the luminous tissue at the tip of a dangling barbel. The luminescence beneath the eyes may be a sexual recognition character.

Top, an anglerfish before feeding and, bottom, after swallowing a prey fish that it attracted by wiggling the lure at the end of the fishing-rod-like appendage on its head. Distensible stomachs allow anglerfish to engulf prey as large as they are. Males in this group of fish serve as little more than reproductive agents. They attach themselves to the body of a female, above right, and eventually become fused to their larger mates; in effect becoming attached testes nourished by the host female's blood.

Large, fast-moving predatory fishes, such as tuna, slash through aggregations of nibblers, scooping up all within reach. Other predators, living at greater depths, ambush nibblers one at a time. Naturally, there is a gradation of feeding strategies between these extremes.

In one group of midwater predators, the fishes' elongate bodies are covered with light-producing tissue, and luminescent lures dangle near their large, fang-filled mouths. Fishes of the genera *Stomias, Idiacanthus,* and *Chauliodus,* as well as many from the family Melanostomiatidae belong to this group. Melanostomiatid fishes are endowed with jagged beds of teeth that fold backward toward the gullet, so that a struggling nibbler cannot escape. Species of *Chauliodus, Idiacanthus,* and *Stomias* are comparably equipped with teeth. Analyses of the stomach contents of these fishes have revealed that they feed largely on myctophids and shrimps with similar depth ranges. The predators tend to stay deeper than their prey, however, using the blackness of the depths as cover while the prey are viewed against the lighted waters above.

The feeding strategy of these predators is that of the "stalker," closely tuned to the vertical movements of their prey populations. Utilizing

tures are cavernous and their distensible stomachs allow them to engulf animals as large as themselves. Because meals may be few and far between in this environment, each feeding opportunity must be seized, whether the prey is large or small.

The physiology of bathypelagic fishes is modified to cope with their austere habitat. Most of them respire slowly, have lightly calcified bones, and bodies with low protein and high water contents. This allows them to exist for long periods between feedings. Physiologist Jim Childress has calculated that the caloric value of a single large myctophid could keep a medium-sized angler supplied with enough energy to last for weeks.

Opportunities for mating must be just as capricious as feeding in deep water because some anglers have adopted an equally bold strategy for reproduction. Males are mere pygmies alongside the females, but they have no need for extensive feeding apparatus or size—their sole function is reproduction. A male seeks out a female and attaches itself anywhere on her body by sinking his teeth into her flesh. The tissues of the two animals fuse permanently and the body of the male degenerates to a lump of tissue surrounding its testes, which are nourished by the female's bloodstream.

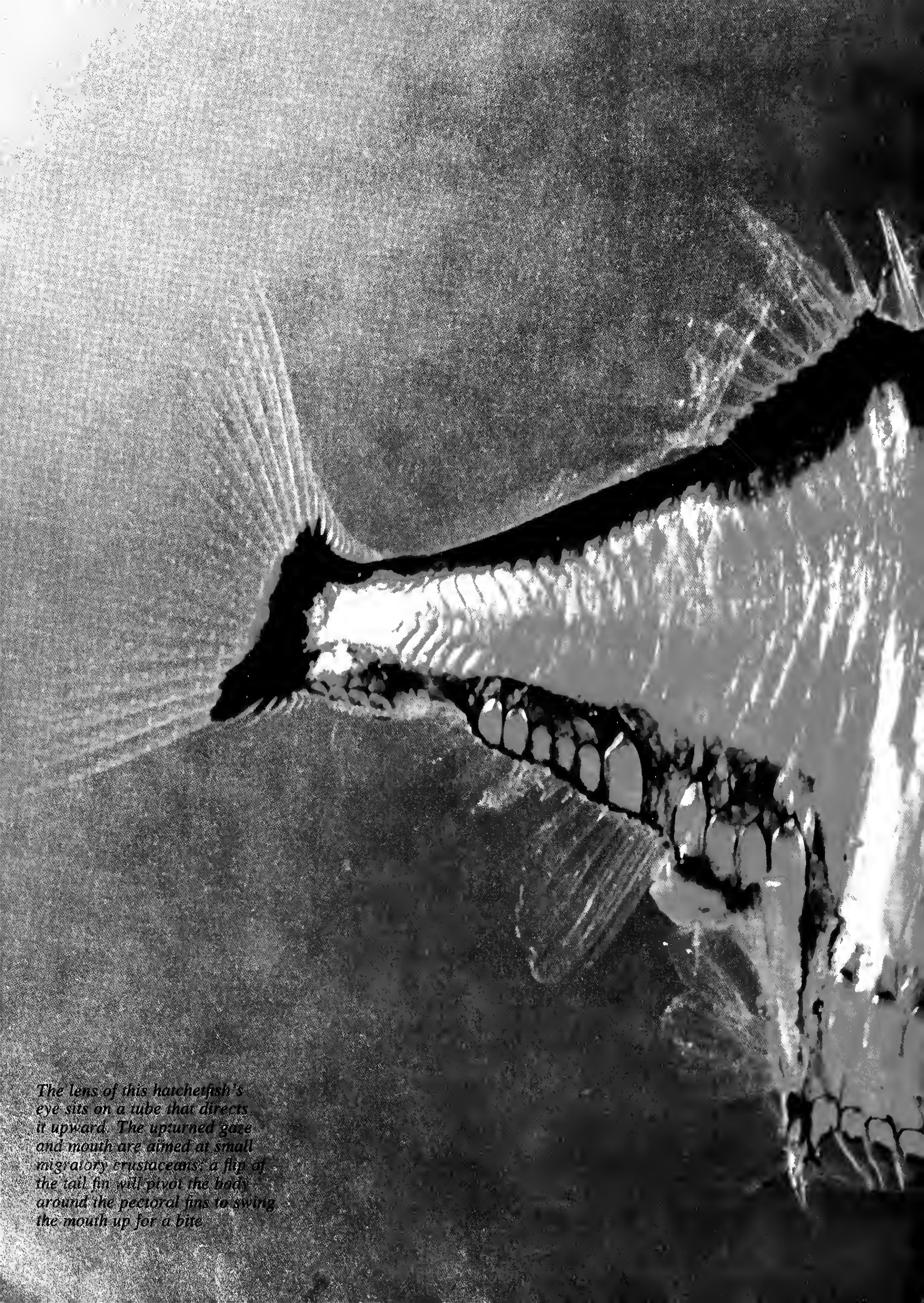
Anglers have ungainly bodies, and many species lack webbing between the rays of their fins. This precludes rapid swimming, so it seems likely that they must remain essentially motionless in the water, awaiting their prey. This is not to say that they are completely sluggish, for their feeding action is a lightning-fast gulp.

Whalefish are another type of ambusher, but one that does not rely on luminous lures. Many species of this type have reduced, or degenerate, eyes, and they rely on a system, called the lateral line, which provides them with the sensory capability of detecting low-frequency vibrations. The lateral line consists basically of a series of tiny filamentous projections, arrayed along the head and flanks of the fish and connected to a nerve network. Their function is the perception of changes in the pressure and displacement of water, presumably related to the movements of other animals.

proximity and the attractiveness of their luminous lures, stalkers maneuver a nibbler close enough for a quick lunge and snap to impale it with their teeth. Stalkers maintain a degree of isolation from competing predatory species by the timing of their activities and the spatial arrangement of their distribution in the vertical plane. They apparently are not segregated through the selection of specific prey.

The "ambushers" are another ecological group of predatory fishes that prey upon the hordes of nibblers and their stalking escorts. Their habitat, the bathypelagic level of the water column, is characterized by coldness, enormous water pressure, and almost complete darkness. The only things visible at this level are clouds, points, and strings of bluish light given off by luminescent organisms. Ambushers lurk like set traps in the enveloping darkness.

Anglerfish are ambushers that exhibit a number of adaptations from which we can speculate on the nature of bathypelagic life. All anglers (with the exception of some specialized males) have luminous lures at the end of elongate fishing-rod-like appendages attached to their heads. Presumably, an anglerfish attracts prey to the vicinity of its mouth, playing the lure (esca) by flexing the rod (illicium). The mouths of these crea-



The lens of this hatchetfish's eye sits on a tube that directs it upward. The upturned gaze and mouth are aimed at small migratory crustaceans; a flip of the tail fin will pivot the body around the pectoral fins to swing the mouth up for a bite.

Most fishes have the lateral line filaments arranged linearly within a simple canal, with pores that open through the skin and scales to the surrounding water. Bathypelagic fishes, however, live in waters that are very still and there is correspondingly less need for the filaments to be insulated from minor disturbances. Lateral line systems with exposed filaments in ladderlike tracks have evolved in some whalefish. This has occurred as an adaptive widening of the canals and an increase in pore size. The information provided by these specialized sensory systems is probably sufficient to determine the location, size, speed, and direction of a nearby, but unseen, moving prey.

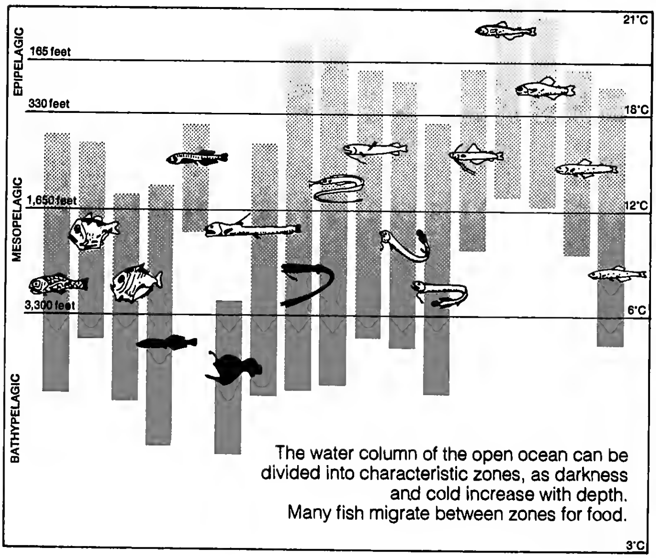
The "hunters" are another group of predatory midwater fishes. These are active fish that seek and pursue their prey through the inky depths of the bathypelagic zone, and well up into the murky mesopelagic. Because of their speed and agility, few large specimens have been collected by the slow-moving, midwater trawls of researchers. Speculations on the life histories of midwater hunters are based on young individuals or adults of the smaller species.

Daggerlike teeth seem to be a common hunter adaptation, along with firm, slender bodies, and well-developed eyes. Often the teeth are barbed, completely covering the floor and roof of a hunter's mouth so that it cannot be closed. Hunters rely on both their visual and lateral line sensory systems; compared with their prey, they are very mobile in both the vertical and horizontal planes.

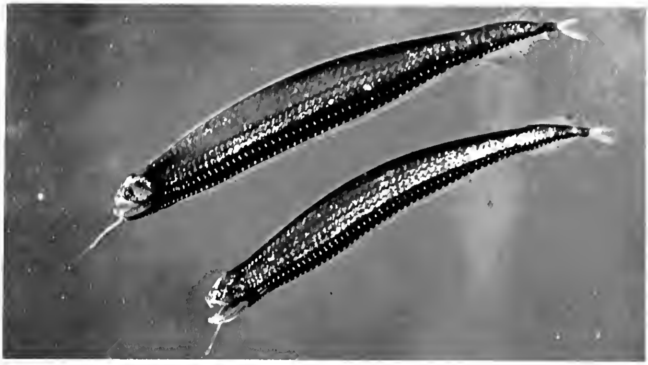
Hunters of the family Evermannellidae have flat, slender bodies that ripple with musculature. These are apparently the only small midwater fish fast enough to regularly include squid in their diet. Another family, the Chiasmodontidae, can stretch their stomachs to accommodate large prey. I have often found nibbler fishes in the stomach contents of chiasmodontids. *Anoplogaster* is a small hunterlike fish whose growth stages occupy succeedingly greater depths. The larvae of most midwater fishes inhabit the near-surface waters as plankton, while the juveniles inhabit greater depths with increasing age until sexual maturity occurs and the descent of depth range is stabilized at the adult level.

These four ecological groups of midwater fishes, each loosely defined by depth range and feeding strategy, are but a portion of the deep-sea fauna. Many other fishes live in this environment, with characteristics and roles that are different from or intermediate to these groups. The groupings are artificial, but they do indicate trends of organization within midwater communities.

The practical reasons for studying midwater ecology are profound. The deep ocean basins contain the largest ecosystems on earth, and the numbers of animals living within them are as yet incalculable. Midwater fishes represent a tremendous potential food resource because they are lower in the food web and thus are orders of magnitude more abundant than the commercial fishes traditionally harvested by man. But we can never hope to properly exploit any of the resources of the open ocean without first learning how its ecosystems work. □



The water column of the open ocean can be divided into characteristic zones, as darkness and cold increase with depth. Many fish migrate between zones for food.



Stomias are stalking predators encased in a gelatinous sheath, left. The reddish flecks within the sheath are luminous tissue that silhouettes the fish's profile. Females have bulkier bodies than males and the lighted profiles may enable the sexes to recognize each other. *Granular teeth of* Pseudoscopelus, *below, may be an adaptation for feeding on crustaceans.*

Sea Otters: Pillars of the Nearshore Community

by John F. Palmisano and James A. Estes

By preying on the animals that graze on kelp, otters in the Aleutian Islands affect the structure of the entire coastal environment

The Aleutian Archipelago of nearly seventy named islands stretches for about a thousand miles in a southwesterly arc from the Alaska Peninsula into the North Pacific Ocean. Most of the islands are mountainous and many contain active volcanoes. All are virtually treeless except for an occasional willow or alder, dwarfed by the wind and northern climate. The climate is one of rain, snow, fog, clouds, and frequent and violent squalls, but an extension of the warm Kuroshio Current moderates winter temperatures and keeps the sea ice-free. In contrast to the bleak climatic conditions is the abundance of wildlife, most conspicuously sea birds and marine mammals. Terrestrial mammals, such as brown bears, caribou, and lemmings, inhabit only the easternmost islands of the chain, which were once part of the mainland.

At the western end of this island world lie the Rat and Near Islands groups. These are ideal study areas, providing a rich opportunity to examine ecological relationships in discrete biological communities. Cut off from one another by deep oceanic passes, they are also geographically far removed from both the Asian and North American continents. These two factors combine to produce isolated biological communities that are relatively simple in their species constituencies compared with biological communities associated with continental land masses. Oceanic passes serve as barriers, preventing immigration of certain species from continents to islands, as well as the free exchange of individuals between islands. Since ecological interrelationships are easier to understand in simple communities than they are in complex ones, the western Aleutians provide an excellent opportunity to study the role of a particular species. In this case, we were interested in looking at how one animal, the sea otter, shapes the ecology of the nearshore community.

Upon arriving at Amchitka Island in the Rat Islands group, we were immediately struck by the dense kelp beds. The kelp is so abundant that in many areas we could not see the rocky ocean floor either from the shore or when diving in the water. Yet at the Near Islands of Attu and Shemya, 250 miles to the west, there

With its powerful jaws and heavy teeth, a sea otter is well adapted to feeding on sea urchins. In the Aleutian Islands, these small invertebrates make up the major part of the otter's diet.

Scott Ransom

are only a few scattered kelp beds. What we did notice here was a dense carpet of large sea urchins, small invertebrates that live on the ocean floor or in rocky crevices and feed on kelp. So completely have the sea urchins grazed the kelp that the ocean floor appeared light emerald, rather than dark brown as at Amchitka.

After studying the marine communities in the western Aleutians, we believe that the sea otter, which feeds extensively on sea urchins, is the primary cause of the differences observed between these communities in the Rat and Near Islands groups. For in the Rat Islands, in addition to a luxuriant growth of kelp, we also saw a large population of otters—drifting in the water on their backs, splashing in large groups, or hauling out on rocks in stormy weather. By selectively taking the largest sea urchins available, sea otters reduce the urchins to a sparse population of small individuals. The resultant release from grazing pressure permits a significant increase in the size of nearshore and intertidal (that area of the shore alternately exposed to air and flooded by the sea) kelp beds and in the richness of associated communities. Conversely, the absence or reduction of sea otters in areas they formerly inhabited (such as the Near Islands) enables sea urchin populations to increase, causing a significant reduction in the size of kelp beds and the diversity of associated communities.

Overgrazing by dense populations of sea urchins has destroyed kelp beds in many areas. When sea urchins are removed from an area the marine vegetation recovers rapidly. Because kelp and beds of sea grass provide food and habitat for a wide variety of marine organisms, they have a profound effect on the entire structure of a region. Any reduction of a particular grazer will affect a variety of other organisms. Therefore, an animal that preys on kelp-bed grazers, as the sea otter does, determines the structure of the entire marine community.

Prior to the onset of large-scale hunting in 1741—the year that Vitus Bering, a Danish explorer employed by Russia, discovered the Aleutians—the sea otter ranged from the northern Japanese Archipelago, through the Aleutian Islands, and along the coast of North America as far south as Morro Hermoso, Baja California. It was virtually wiped out by eighteenth- and nineteenth-century fur hunters, who valued its dense, rich brown coat, but has since come back and now inhabits the more remote portions of its original range—the Kuril, Commander, and Aleutian Islands, and parts of southeastern Alaska. There is also an isolated population off the coast of central California, and recent transplants have reintroduced the otter into Oregon, Washington, and British Columbia. It seems likely that the sea otter's range will continue to expand.

The present sea otter population of Amchitka is about 60 animals per square nautical mile. Otters stay close to shore, floating in the sheltered waters and diving for their food in waters generally no deeper than 180 feet. Most of their food—crabs, sea urchins, bottom-dwelling fish, and octopus—is found on the ocean floor, but they surface to eat, floating on their backs while keeping the food on their chests. Sea otters have incredibly powerful jaws and heavy teeth to cope with their shellfish diet, but they also open shells by smashing them against stones, calcified algae, and other shells placed on their chests. Otters require almost 25 percent of

Although an otter takes most of its food from the ocean floor, it surfaces to eat, right, floating on its back and smashing open shells against a rock held on its chest. Kelp flourishes at Amchitka Island, below, where a large population of otters feeds on herbivorous sea urchins. Dense kelp beds, in turn, support a variety of other animal populations.

John Palmisano

Jeff Foott; Bruce Coleman, Inc.

their body weight daily in food. Considering that their average weight is about 50 pounds, foraging sea otters at Amchitka consume about 200,000 pounds of animal biomass (live weight) per square nautical mile each year. Obviously, a high-density sea otter population is an important member of the nearshore community.

Sea otters have inhabited the Rat Islands at these high densities for the past twenty to thirty years. In the Near Islands, however, the once abundant sea otter population was virtually extirpated by hunting. Owing to the deep and wide oceanic passes separating the two island groups, until recently there were only a few immigrants from the Rat Islands to the Near Islands group. Since 1959, however, there have been scattered reports of sea otters in the Near Islands, and during a visit in 1975, we counted more than 250 otters at Attu. This immigration is probably the result of individuals leaving the densely populated Rat Islands. Since we also saw sea otter pups at Attu, local reproduction is also contributing to the growth of the Near Islands population. At the time we did our study, however, there were few enough individuals that the two island groups could be compared on the basis of their otter populations.

Despite the physical similarities and proximity of the two island groups, there are major plant and animal differences between the marine communities of their rocky nearshore and intertidal areas. In the Rat Islands a mat of ungrazed kelp extends from the intertidal region over most of the rock surface to depths of about 75 feet. Both brown and red algae are abundant. In turn, the abundance of kelp affects other marine life, including sessile (attached) filter-feeding invertebrates such as barnacles and mussels, which cannot compete with kelp for space and are consequently rare in the Rat Islands. Furthermore, by sheltering the shore from wave action, kelp beds reduce turbulence, and the accumulating sediments smother sessile invertebrates.

While kelp-eating invertebrates—chitons as well as sea urchins—are small, inconspicuous, and scarce in the intertidal region of the Rat Islands, relatively high densities of sea urchins do occur in more protected cracks and beneath the anchoring devices (holdfasts) of kelp. Beginning at depths of 30 to 60 feet, sea urchin densities increase and vegetative cover decreases with increasing depth. At these depths, sea otters and other predators, including diving birds such as eider ducks, have greater difficulty taking urchins.

Conversely, at the Near Islands, the kelp is heavily grazed by dense populations of sea urchins and to a lesser extent by limpets and chitons. In many areas, sea urchins almost completely carpet the sea floor immediately adjacent to the intertidal region, although densities decrease dramatically in deeper waters because of the scarcity of kelp. There are also

Robert Woolery

Robert Woolery

Unlike most marine mammals, otters lack a subcutaneous layer of fat. To retain body heat, they roll in the water, above, trapping air in their long fur. Underwater dunks, right, prevent the fur from matting and losing its insulating qualities.

extensive mussel beds and dense populations of barnacles in the intertidal region; whereas in the Rat Islands these invertebrates average four and five per square yard, respectively, in the Near Islands, they average 700 and 1,200 per square yard. Intertidal sea urchins are not only more dense, averaging eight per square yard in the Rat Islands and eighty in the Near Islands, they are also twice the size (the largest are four inches as opposed to less than two inches) of those in the Rat Islands. Chitons, virtually unnoticeable at one per square yard in the Rat Islands, are abundant in the Near Islands, averaging forty per square yard.

Because climate, sea state, tidal ranges, and mean tidal levels are similar at both island groups, and because we compared only similarly structured coastlines, there is no doubt that the differences in marine vegetation and associated marine invertebrates result from the presence or absence of sea otters.

More far-reaching consequences of these relations become apparent when we consider the source of food in these island groups. The energy for sustenance in any biological community must ultimately originate from photosynthesizing plants. These are the "primary producers," those that use light energy to produce food for themselves (autotrophs), for plant-eating animals (herbivores), and ultimately for flesh-eating predators (carnivores). In the nearshore community of the western Aleutians the primary producers fall into three groups: terrestrial plants, phytoplankton (microscopic algae suspended in the sea), and kelp. From earlier studies we know that terrestrial plants and phytoplankton contribute little to primary production in the Aleutian Islands, whereas the primary production of kelp is very high. In fact, kelp beds are among the most productive habitats on earth.

All animals are ultimately dependent upon plant production for their energy; therefore, by preying on kelp-eating urchins, sea otters affect many species that inhabit the Aleutian Islands. Certain animals, such as fish, are directly dependent upon kelp for food and protection. Not surprisingly, while scuba diving at Amchitka in the Rat Islands we noticed abundant fish populations, whereas

fish are sparse at Attu and Shemya in the Near Islands. Furthermore, fish constitute a critical link in the food web leading to higher-level predators. Both harbor seals and bald eagles, for example, are abundant at Amchitka, while in the Near Islands, harbor seals are rare and bald eagles are totally absent. Although we do not have conclusive proof that these patterns of abundance and distribution are directly linked to the sea otter–sea urchin–kelp interrelationships, sea otters and kelp beds, as well as fish, harbor seals, and bald eagles, were probably once abundant throughout all the Aleutian Islands, including the Near Islands group.

Far from the Aleutian Islands, along the coast of central California, these interrelationships between otters and marine invertebrates have been the subject of great controversy, as commercial and sport shellfish hunters resist the reintroduction of the otter in California waters. While sea otters are no doubt incompatible with human exploitation of such shellfish as abalone and pismo clams, they do not cause the extinction of these prey items. The coexistence of the otter and its principal prey in this system is the result of at least several million years of evolution. Rather, the controversy developed because humans began heavily exploiting this community's resources after the sea otter had been essentially wiped out throughout most of its original range. Consequently, some of the abundant marine resources Europeans first encountered along the west coast of North America were probably the result of a major, human-induced ecological disturbance, not a community that had evolved naturally. Without a natural predator, shellfish abounded and could be exploited for both recreational purposes and economic gain. Not surprisingly, considerable disgruntlement has accompanied the re-

turn of the sea otter in California. In turn, animal preservationist groups have entered the arena, arguing that sea otters are natural members of the marine community, that while they deplete invertebrate populations, they enhance other aspects of the community, such as primary production from kelp beds.

Unfortunately, ecological interactions involving sea otters, invertebrates, and kelp are not as clear in California as in the western Aleutians. For one thing, the nearshore community is more complex; other predators of sea urchins, such as sea stars and sheepshead fish, inhabit California waters and we do not know the importance of their predation or how their ecological roles have changed in the absence of sea otters. Furthermore, there are several competitive grazing invertebrates in California, such as abalone, sea urchins, crabs, and snails, whereas in the western Aleutians, the sea urchin is the only conspicuous grazer. Finally, since nearshore communities in California have been affected by recent human activities—kelp harvesting, invertebrate hunting, and urban and industrial pollution—one cannot easily isolate the role of otters in this community.

Even so, there can be little doubt that sea otters are important components of nearshore communities in the waters off California, as they are in the entire northeast Pacific Ocean. The loss of this member of the marine community, however we have accommodated to such a loss or, as in the case of the shellfish industry, benefited from it, has had a profound effect on the nearshore ecosystem. The Aleutian Islands study has clarified the key role of the sea otter in structuring a marine community; we hope that we will gain similar understanding of its place in more complex communities. □

Holding a mussel against its chest, an otter drifts in the waters off Monterey. Otters are returning to their northern range, but only an isolated group inhabits the central California coast.

Scott Ransom

Recipe for a Planetary Ocean

Strict conditions of size, temperature, and distance from the sun must be met if a planet is to have great seas

The earth is a watery planet. Some 70 percent of its surface is covered by ocean that is more than six miles deep in some spots. The land surface pokes up through the sea in places, but continents and islands make up only about 30 percent of the earth's surface. The earth is a solid planet with a partial liquid cover. Is this a common situation? Can we expect other planets to have an ocean? If they do, will it always be of water as on the earth or is a planetary water ocean a rare occurrence?

To answer these questions, let us consider the requirements for an ocean. First, it must be made of a substance that is liquid at the surface temperature and atmospheric pressure of the planet. Second, the substance must be made of cosmically abundant elements so that enough of it will be found on the planet to form an ocean.

Starting with the second condition, only a few of all the elements in the solar system meet the requirement of abundance. Since some of these tend on planets to combine with each other, a list of the only ingredients from which a planetary ocean could be composed can be narrowed to the following ten substances: hydrogen (the most plentiful element in the cosmos), helium (the second most abundant), neon, argon, methane (a hydrocarbon), ammonia (a compound of nitrogen and hydrogen), water, hydrogen sulfide, the silicates (silicon-oxygen compounds of various metals, which make up more than 95 percent of the earth's crust), and a nickel-iron mixture in the proportion of one to nine.

These ten ingredients can, in turn, be divided into three groups according to the state—gas, solid, or liquid—in which they might be found in quantity. The first group includes hydrogen, helium, neon, and argon. These elements have boiling points below −170° C and are going to be gases under all but the most unusual conditions. They are therefore unlikely to be ocean-forming substances.

The second group includes the silicates and nickel-iron. These materials have melting points above 1,000° C and are going to be solids under all but the most unusual conditions. Consequently, they too are unlikely to be ocean-forming substances.

That leaves the third group of ingredients—methane, ammonia, water, and hydrogen sulfide. These are the only substances that, under conditions of hydrogen excess, might be found in the liquid state at reasonable temperature conditions and that can be present in sufficient quantities to form an ocean.

Next, let us take up the conditions under which planets themselves can form (and "planet" here is meant to include such smaller bodies as satellites and asteroids). The chief variable in the process is the distance from the central star around which the planets orbit. Planets can form either relatively close to or relatively far from the star. If a planet forms close to the star, its temperature will be comparatively high and all the atoms and molecules that come together to form it will be moving comparatively rapidly. In this situation, the small and therefore particularly nimble atoms of helium and neon cannot be held by the gravitational field of the forming planet; neither can the small two-atom molecules of hydrogen. They will escape into space. Since hydrogen, helium, and neon—from the first group of potential ocean-building substances—together make up some 99 percent of all the atoms or molecules in the original gaseous mix from which stars and planets develop, a planet forming out of the leftover material, and therefore small in size, cannot have a strong gravitational field.

If it forms sufficiently close to the central star or if it is particularly small, a planet's gravitational field cannot even hold the somewhat heavier molecules of the third group of substances—methane, ammonia, water, and hydrogen sulfide, often called "volatiles" because even when they are liquid they evaporate easily and turn to gases. All that is then left are the silicates and nickel-iron, the atoms and molecules of which are bound tightly to each other by chemical forces and do not require a strong gravitational pull to be held. This means that particularly hot bodies such as Mercury, the planet closest to the sun, and particularly small bodies such as the moon must be entirely solid and can have no oceans.

For an ocean to exist, a planet must be large enough and have the right temperature and pressure range for the purpose. The requirements are stringent. Thus, Mars, which is larger than Mercury, is big enough to hold some volatiles but not enough of them to make up an ocean. In addition, Mars is so cool that most of its volatiles exist in the frozen state. Venus, on the other hand, which is even

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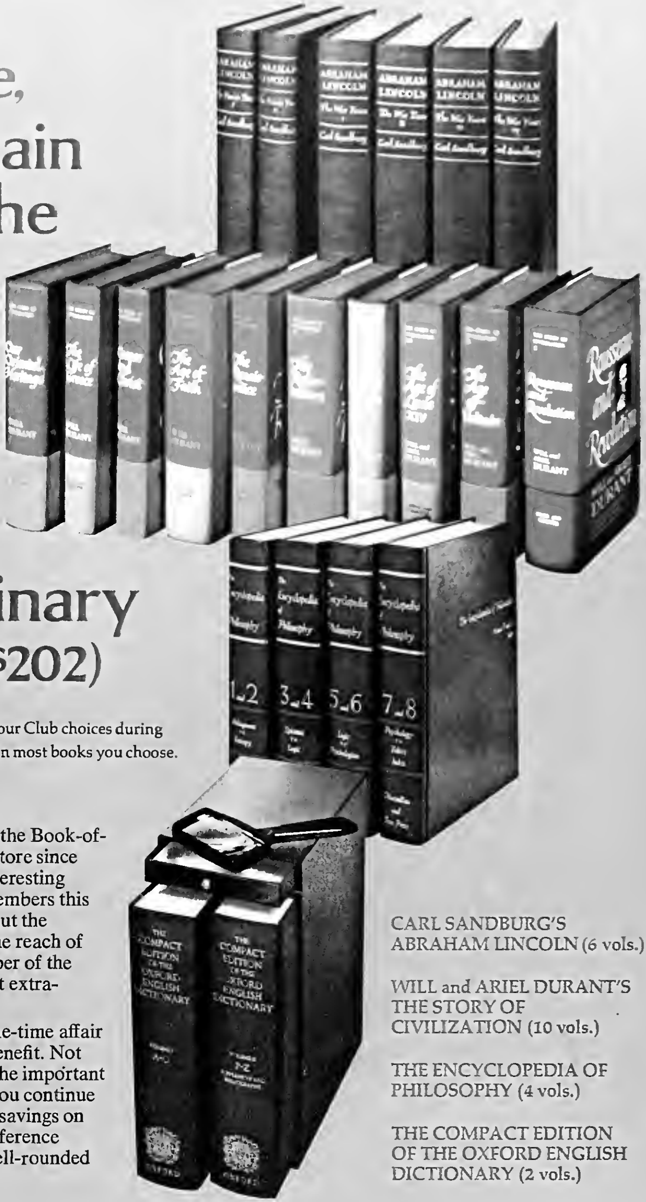

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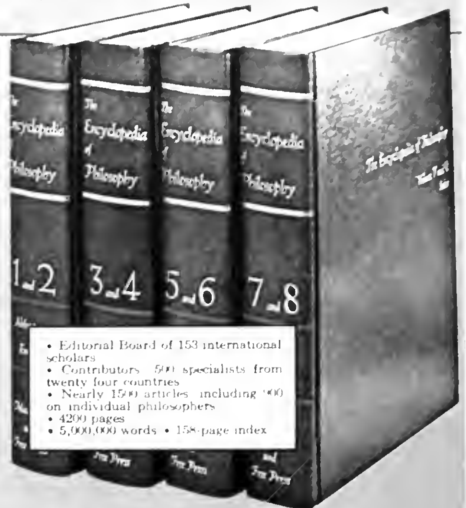

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larger than Mars and has more of the volatiles, is so warm that all of them are in the gaseous state. Under the thick Venusian atmosphere, the surface of Venus is solid material. The planet has no oceans.

A planet at least the size of, but considerably cooler than, Venus could in theory retain ocean-sized quantities of volatiles and maintain most of them in the liquid state. But under those conditions, which volatile would form the ocean or would it consist of a mixture of substances?

Suppose a planet is small enough to lose its free hydrogen but large enough to retain the volatiles. Without free hydrogen, chemical processes take place that tend to oxidize the ammonia to nitrogen (which remains gaseous) and water. There is also a tendency for the methane to oxidize to carbon dioxide (which remains gaseous) and water. Finally, there is a tendency for hydrogen sulfide to be converted to sulfur, which is a solid at earthly temperatures and which combines with other solids in the planet's crust (if it has one) and water. Such a planet would be left with only one volatile in ocean-sized quantities—namely, water. The earth is such a planet and that is why it has oceans.

What about objects that condense at comparatively large distances from the central star? Out there, the small atoms and molecules of helium, neon, and hydrogen are cold and therefore sluggish enough to be captured by the gravitational field of the developing body, whose mass can accordingly increase rapidly. With increasing mass, the gravitational field grows ever more intense and the small atoms and molecules are held even more efficiently.

The result is the formation of a giant planet, such as Jupiter, Saturn, Uranus, or Neptune, made up very largely of hydrogen. Solid components, if any, make up an inconsiderable fraction of the material at the planet's core, and we have what used to be called a "gas giant." To be sure, it is now thought that Jupiter, although composed mostly of hydrogen, compresses that gas into a red-hot liquid and that the giant planet may be an enormous liquid sphere. It might be considered *all* ocean, but the liquid is not ocean in our sense of a partial fluid cover of a solid planet with dry land emerging here and there.

The far reaches of a planetary system need not contain only giant planets, however. Minor bodies are also formed out of leftover cosmic materials, and these can be as small as or smaller than any of the bodies of the inner planetary system. Small bodies that are distant from the central star are cold, but even so their gravitational fields are not strong enough to retain the light atoms and molecules of hydrogen, helium, or neon. Most of those substances have in any case been swept up by the giant planets. Nevertheless, the small bodies of the outer planetary system can hang on to the volatiles, but the temperatures of those objects are so low that ammonia, water, and hydrogen sulfide, if present on them, will exist only in solid form. In the extreme far reaches, even argon and methane will be frozen.

The result is that the small bodies of an outer planetary system are generally a mixture of ordinary solids, such as silicates and nickel-iron, and of "ices" made of frozen volatiles. In our own solar system, this is true, for instance, of the satellites of Jupiter and of the comets. It would seem, then, that the small bodies of an outer planetary system cannot have an ocean either—unless, perhaps, certain restrictive conditions are met in just the right way.

The possibility of an ocean existing on a body that far from the central star arises in connection with methane, which boils at a temperature of $-161.5°$ C. Objects in the nearer portions of the outer planetary system would be warm enough to keep the methane as a gas; bodies in the outermost portions would keep it as a solid. What about the region in between?

Suppose there were a body at just the right distance from the central star to keep methane in the liquid state. If that body were large enough to hold methane, but not large enough to hold hydrogen, it might acquire enough methane to develop a fairly thick atmosphere of that substance—with some of it in liquid form at the body's surface. Unlike the other volatiles, the molecules of methane can, under certain conditions, combine with each other to form larger molecules that can be liquid even though methane itself is normally a gas. These larger molecules have properties rather like lighter fluid.

As it happens, there is a body in our solar system that might possibly qualify in this respect. It is Titan, the largest of Saturn's ten satellites. In terms of volume, it is the largest satellite in the solar system, even larger than the small planet Mercury. Titan has a fairly thick atmosphere—it is the only satellite known to have a sizable one—that contains methane. Does Titan have a hydrocarbon ocean covering much of its surface? That is at least conceivable.

To summarize, for an astronomical body to have an ocean on its surface, it must meet very stringent conditions in terms of size, temperature, atmospheric pressure, and gravitational intensity, with the result that only a small proportion of the planetary bodies in the universe could be expected to have one. On the other hand, any astronomical body that is part of a planetary system and happens to be about the earth's size and temperature is almost sure to have an ocean, and that ocean is very likely to be composed of water.

Conditions for an ammonia ocean or a carbon dioxide ocean are much more stringent than for water. If a planet is cold enough to collect oceanic amounts of ammonia, it will probably collect enough hydrogen to become a giant hydrogen body. As for carbon dioxide, it is only liquid at low temperatures and high atmospheric pressures and the combination is not very likely to exist on a nonhydrogen planet.

There is a chance that an earth-sized or somewhat smaller astronomical body that is much colder than the earth could have one other variety of ocean that is possible—namely, hydrocarbon.

Thus, to the best of our knowledge, the score for our solar system is one water ocean on earth, and possibly one hydrocarbon ocean on Titan.

Isaac Asimov, who has a Ph.D. in biochemistry, has written more than 170 books and countless magazine articles on a variety of subjects, ranging from science to science fiction and literature.

Lobster Tales

by Michael Berrill

The location of lobster nurseries is still a mystery

Everywhere in the world that there are lobsters and lobstermen the refrain is the same: there are fewer lobsters to be caught. You used to be able to collect a quick dozen from rock pools in New Zealand or Mexico; in New Brunswick, farmers fertilized their potatoes with them. Now they are gourmet food; a tourist's treat.

With overfishing, poaching, and loss of suitable habitats due to pollution and shoreline development, lobster populations are dwindling away. To halt, and begin to reverse, the decline of this valuable marine resource, a series of socioeconomic problems, which include poaching, unemployment among lobstermen, and even the high cost of the animals to consumers, must be solved.

Most fisheries try to protect lobsters so that they may breed at least once before they are caught and cooked. But virgin, undersized lobsters taste just as good and can be sold, albeit carefully, for almost as much as the legal-sized ones—and so poaching is a global pastime, either for fun or out of necessity.

Perhaps one of the lobster species will in time be domesticated and grown rapidly and efficiently far from its natural habitat. Or perhaps ocean ranching, in which managers will provide lobsters with abundant food and protection from predators, might someday become successful. However, the first technique for meeting the world's lobster demand would undermine current fisheries and the lobstermen involved; the second would demand an extraordinary degree of policing.

At present neither possibility seems more than a promise or a threat, and this is due, at least in part, to a surprising state of affairs. Despite worldwide interest in lobsters, we know remarkably little of their behavior and ecology, especially of young ones under a year old.

The lobsters that people eat come in two varieties. One has large claws containing meat as sweet tasting as that in its tail; the other lacks large claws and has a pair of large, spiny, but essentially meatless antennae. Large-clawed lobsters, or homarids, support thousands of lobstermen on both sides of the North Atlantic, from Cape Cod and Maine to Ireland and Brittany. The clawless, spiny lobsters, called palinurids, are caught throughout the warmer temperate, subtropical, and tropical oceans. These are marketed simply as "lobster tails."

The two species of homarids and the approximately twenty species of palinurids that occur in enough numbers and in shallow enough water to be fished commercially have more in common than palatability. They all breed for the first time at about the same size and age (eight to ten inches long and about five years old), and all have at least the potential for many years of further growth and reproduction. Although the adults of all species hide in burrows or caves in the daytime, the palinurids are gregarious while the homarids remain solitary. At night they all forage individually, preying upon mollusks, worms, other crustaceans, and sea urchins. Most of the adults migrate in and out of warmer, shallower water during breeding seasons, and mature females carry their eggs glued in grapelike clusters to their swimmerets. The eggs hatch into plank-

An adult clawed, or homarid, lobster feeds on a fish head. The meat in the claws is a nutritious, but declining, food resource for humans.

Jane Burton; Bruce Coleman, Inc.

tonic larvae that, after weeks or months at the mercy of surface currents, molt into miniature versions of their parents and settle to the bottom. It is at this stage that virtually nothing is known of their life in the wild.

Newly settled homarids and palinurids don't appear to move into habitats associated with the adults until they are one or two years old, perhaps living in some kind of nursery habitat until that time. What is the nature of these nurseries if in fact they exist? Are the needs, and hence the behavior and ecology, of the newly settled lobsters significantly different from those of the adults? Domestication, ranching, or even the simplest management cannot be successful unless these questions are answered.

If you cannot find newly settled lobsters in the ocean, you can attempt to culture them in a laboratory, observe their behavior in a variety of conditions, and then perhaps predict what they are up to in the wild. I have raised several hundred individually isolated homarids from the time they hatched, through the larval stages, and until they were two to three months old. The first three planktonic larval stages last only a couple of weeks, and the larvae are hardy and easy to feed. As a result the culture technique is simple even if it is time consuming.

Once each of these larvae molted into its fourth larval state, it ceased swimming around its culture jar, settled on the substrate of sand or mud, and proceeded to burrow. When the substrate was sand with a pebble lying on the surface, the stage 4 lobster dug a cave with two openings under the pebble. When the substrate was mud, the lobster dug a U-shaped tunnel that reached about an inch below its two surface openings. Although some hours or days might pass before a newly molted stage 4 lobster burrowed for the first time, its first burrow was well constructed. Each dug proficiently using a combination of techniques: debris was "bulldozed" out of the burrow by pushing loads with the claws and blown out behind by beating up a current with the swimmerets; occasionally, an individual would curl its tail around debris and scoop it out.

What fourth stage lobsters do so consistently in captivity they are likely to do in their natural habitat. There they probably seek out a substrate they can burrow in: one that is soft and has surface objects such as stones or shells under whose edges they can dig. They should then remain in their burrows during the first settled stages, for they are still so small that almost any foraging predator can handle them. As they become larger, perhaps they cannot find enough food in the region of their burrows or perhaps the substrate cannot stand up to the increasingly large-scale excavations. As they become large enough, the juveniles may be capable of successfully defending themselves against smaller predators. They may then leave their nursery habitats and invade the environments in which adults are commonly found.

The problem still remains, however, that wherever stage 4 lobsters settle, whether in deep or shallow water, on mud substrates or elsewhere, they have not been found in any numbers by biologists. My observations on their behavior in captivity simply indicate that they ought to be down there, dispersed on the mud, tunneling avidly.

Spiny lobsters, the palinurids, present similar questions, but culturing planktonic larvae has proved almost insurmountably difficult. The mature female carries her eggs for only a month or two, and the phyllosoma, or planktonic larvae, that hatch out are all eyes and legs, don't look much like lobsters, and are less than one-tenth of an inch long. They disperse with the currents for as long as a year, molting perhaps a dozen times as they grow to several inches in length. Preying upon other planktonic animals, their own numbers are no doubt vastly depleted by predation. The survivors somehow find their way back to the coastline where they hatched, there to metamorphose to the first stage that looks anything like a spiny lobster: the puerulus. The planktonic life is just too long, their food requirements are unknown, and the larval stages too intolerant of anything but perfect oceanic conditions for lab culture of spiny lobsters to be worth the time, effort, and failures involved.

The palinurid puerulus, like the homarid fourth stage, is the first settling stage. The puerulus has short antennae, has lost the long larval legs, but is still transparent. This stage lasts about a week before molting into the first of many postpuerulus and juvenile stages. The puerulus and postpuerulus spiny lobsters are about as

Ramming itself tail first into a crevice, a spiny, or palinurid, lobster presents an effective defense against most predators. The long antennae are used in intraspecific encounters.

hard to find as their homarid counterparts. They probably settle into extensive, dense sea-grass beds or into rock crevices where grass beds are absent. In either case, they find spaces so small and well dispersed that hunting them is a frustrating and usually fruitless task.

To capture the pueruli, biologists have begun to devise traps consisting simply of a substitute settling substrate, and a variety have been tried in Caribbean, Australian, and New Zealand waters with varying degrees of success. The pueruli are not caught in enough numbers for commercial purposes, but captives are numerous enough to provide information about the time of year most of them settle and to provide someone like me with enough individuals to observe.

Observations of two palinurid species in particular, *Panulirus argus* of the Caribbean and *P. longipes* of West Australia, have led me to a number of conclusions about the puerulus and postpuerulus behavior of these species and, by implication, about palinurids in general.

The puerulus and postpuerulus will hide in almost anything for protective cover—under shells and rocks, among clusters of long-spined black sea urchins, and among the roots of sea grasses, for example. They will even climb blades of sea grass in an attempt to hide from predators. They do not dig or burrow but ram themselves into spaces, tail foremost. Like older individuals, they are gregarious and will share a hiding place even when other hideouts are available. This gregariousness is modified by aggressiveness, for they spread themselves out in a hiding place and are intolerant of close crowding unless under stress. When disturbed or attacked, however, they cease squabbling and tolerate a much greater degree of crowding.

Many palinurid species are no-


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torious for their ability to make harsh, rasping sounds by rubbing an extension of the basal segment of the antenna against a shieldlike region of the carapace below the eye—a kind of stridulation. These rasps are thought to have some antipredatory function.

The puerulus has only the rudiments of the two parts of the sound-making apparatus and so is silent, but the organ becomes operative when the puerulus molts to its first postpuerulus stage. Using a hydrophone, I recorded the rasps of many postpueruli and found, not surprisingly, that the rasps were of higher frequency and much lower amplitude than those of older individuals. What did surprise me was that the postpueruli rasped only at each other during their conflicts over limited food or space, and that rasps did not occur in response to attack by a predator. Instead, antipredatory behavior consisted of scooting rapidly backward, followed by an abrupt cessation of movement, all in silence. When a predator (usually a small fish in my experiments) did see a postpuerulus long enough to catch it, my hydrophone picked up loud, crunching noises, but never any rasps.

It seems, then, that the rasps of the postpuerulus indicate a rather high-level aggressive act by one individual against another. Perhaps even in adults, rasping is used primarily for communicating degrees of aggressiveness to other individuals and is of little direct value in antipredatory behavior. Alternatively, rasping could have more than one function, deriving a second, antipredatory one as the lobster grows large enough for spines and antennae to provide it with some initial protection.

The antennae of a palinurid are effective weapons, and this is true even of postpueruli. In the latter stage, antennae are used, not against predators, but in aggressive intraspecific conflicts, and antennal growth is rapid compared with growth per molt of the rest of the body. Just as they do in adults, the long sweeping antennae can push other, smaller lobsters away, and insure their possessor some degree of private space, even in crowded conditions. Palinurid ag-

An inhabitant of tropical waters, the sand, or shovel nosed, lobster, left, uses its truncated antennae to dig into the sand as an escape from predators. Related to the spiny lobsters, the species has been little exploited commercially. A stage 3 planktonic larva of the American lobster, below, will float in the surface currents of the ocean until its next molt. At stage 4, it will settle to the bottom to maturate in nursery habitats that have not yet been discovered. During the three planktonic stages, the larvae suffer heavy predation.

gression, from postpuerulus to mature adult, consists mostly of antennal sweeping and noisemaking and results in little or no damage to the combatants. Such restrictions to damage are vital if gregarious behavior is to persist. In contrast, when homarids are forced into crowded conditions, which they seldom meet in nature, they may do much harm to each other unless their claws are clamped shut.

Of all palinurids, *P. argus* of the Caribbean has been attracting special attention. When the time comes for the autumn migration into deeper water, the adults, unique among all spiny lobsters, migrate by forming long, single-file queues and walking off together. Queuing migration is particularly difficult to account for as no other lobster is known to engage in such behavior.

I looked for queuing behavior in postpueruli and young juveniles of *P. argus,* expecting it to be a behavior characteristic only of the mature, migrating adults. Instead I found that when I released them on open stretches of sand, the small lobsters would also walk off in single file, the antennae of one individual touching the body of another immediately ahead. Any individual could be a leader, and the curious queues persisted until they encountered the protective cover of grass beds or caves, whereupon they broke up and hid themselves separately. Since postpueruli walk in queues, then queuing itself seems to be more than just part of migratory or reproductive behavior. One implication is that queuing provides some safety from predators.

The most bizarre of my observations on queuing behavior by pueruli and juveniles of *P. argus* concerned their actions when held in a large tank with caves arranged along one side. When one lobster was jostled or evicted from a crowded cave and began walking away, the evictor usually left the cave as well and hooked on behind the evictee. As the procession of two walked by the mouths of other caves, the resident lobsters were drawn out as if by a magnet, and another queue was born. The adaptiveness of this can only be a subject for speculation.

Despite their similarities, ho-

marids and palinurids differ in some critical ways. They appear to use divergent habitats as nurseries, they hide themselves in different ways, and their aggressive displays have little in common. Palinurids don't tunnel, presumably because they lack the equipment for the job and because they have ample hiding spaces, making burrowing unnecessary. The less damaging conflicts and more elaborate communication of palinurids, compared with those of homarids, are probably correlated with their gregarious sharing of hiding places.

Gregarious behavior, wherever it occurs, from fish schools to wolf packs, implies some degree of social organization. Social behavior itself is now understood to be but one of many adaptations by an organism to its particular environmental stresses. For palinurids to be gregarious and homarids not, the stresses the two groups face must somehow differ. However, both groups are solitary while foraging for food and mating is not a communal affair. About the only possibility left is that they have different sorts of predators and so have evolved different antipredatory strategies.

A large lobster, no matter what kind, can hold off most predatory fish unless they, in turn, are very large. Few fish could prey successfully on a lobster in a burrow or in the back of a cave. The palinurids, however, share the warmer oceans with another kind of predator, one that is efficient, rapacious, and agile as it forages upon the sea bottom—the octopus. Even if it is larger than the octopus, a palinurid on its own hasn't much of a chance; its spines and antennae are of little help. However, a crowd of palinurids presents a far more formidable joint armor, and smaller individuals would derive some protection against the insidious octopus arms. So palinurid gregariousness may have evolved in response to the predatory ability of the octopus.

There are some striking coincidences in the distribution of lobsters and octopods, and one of the best examples occurs on the eastern and western shores of the Atlantic. *Octopus vulgaris* is the dominant octopus species on both sides of this ocean. It lives in relatively shallow regions and avoids particularly cold water. On the western shore of the Atlantic, its range is from North Carolina to the hump of Brazil: a range practically identical to that of *P. argus*, the only truly abundant palinurid in the western Atlantic. On the eastern side of the Atlantic, a number of palinurid species are common from the English Channel to the Cape of Good Hope, and once again this distribution is perfectly mirrored by *O. vulgaris*.

In contrast, the homarid of the west Atlantic, *Homarus americanus*, doesn't extend much farther south than Cape Cod, and it doesn't meet up with *O. vulgaris*. The homarid of the east Atlantic, however, does overlap in the south of its range with *O. vulgaris*, as well as with the more northern of the palinurids. Since *O. vulgaris* can tolerate colder water than it is usually found in, it would appear that its range is effectively limited by the range of its favored food; that is, it can prey far more successfully on palinurids than on homarids or other animals. Large homarids may be able to defend themselves against *O. vulgaris* by using the crushing power of their claws.

Although cephalopods dominated the oceans from Ordovician to Triassic times, the soft-bodied benthic octopod does not appear in the fossil record until the Upper Cretaceous. The first palinurids have also evolved since then, and so both groups are apparently relatively recent forms. A close relative of present-day palinurids diverged early from the ancestral palinurid stock and evolved into a group of lobsters called scyllarids, the sand, or shovel-nosed, lobsters. The phyllosoma larvae of the scyllarids are practically indistinguishable from those of palinurids, but adult scyllarids are quite different. Their truncated antennae are used to dig in sand where they stay hidden and solitary much of the time. Sand burial may be a good defense against an octopus.

And so a theory, based on circumstantial evidence and difficult to prove, emerges. The gregarious daytime habit of palinurids may be an antipredatory adaptation specifically against octopods. Spiny armor and antennae may have evolved in palinurids to provide them, especially when grouped together, with a better defense against octopus predation than what any individual could muster. This gregariousness could only have evolved if much of their antagonism toward one another diminished and more complex communication mechanisms developed.

The two large homarid species, on the other hand, remained in cold northern waters, clawed and solitary, capable of at least limited defense against octopods. And the distribution of *O. vulgaris* spread throughout the inshore waters where palinurids were common. The octopus probably developed techniques to prey on the spiny lobster with sufficient success despite the latter's gregariousness, possibly by capturing them at night when the lobsters forage individually. The result of these events would then be the familiar balance of predator and one of its favored prey, with the behavior of the prey dominated by a need for a reasonable antipredatory strategy.

In the past few decades, of course, humans have become rapacious, insatiable predators of both homarids and palinurids. Unlike the octopus, however, we aren't in balance with our prey. The socioeconomic and biological problems currently preventing the successful management, culture, and farming of various lobster species must be solved. To do so, more must be learned of the behavioral ecology of the various young stages. Nurseries may be located and protected and predator-free ranches established. Someday, domestication of lobsters will probably become a reality, and through selective breeding, a fast-growing, disease-resistant species with fine, savory meat will be produced. But will lobsters continue to be the food of the rich, too expensive for the poor and protein starved to be able to afford even if they catch them? The human problems, the so-called socioeconomic ones, will be far more difficult to solve. □

A spiny lobster, or sea crayfish, scavenges for food off the coast of east Africa. Pairs of swimming legs provide locomotion. The meat from the abdomen is marketed as "lobster tail."

S.C. Bisserot; Bruce Coleman, Inc.

Common Eider (male)

Fred Bruemmer

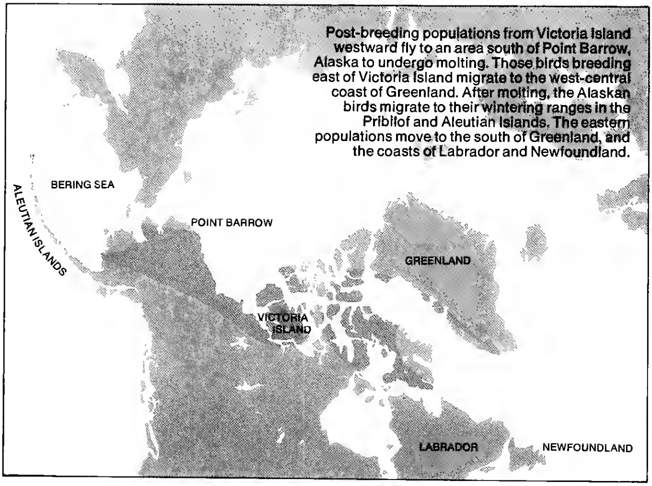
Flight of the Sea Ducks

*Their migration routes have been charted.
Their breeding biology is known.
Their eggs, meat, and feathers have long been used by man.
But eiders at sea remain an enigma.*

Nesting in colonies that can number hundreds of birds, the eiders are among the most conspicuous of tundra-breeding ducks. Although female eiders are a study in grays and browns that match the arctic tundra, the males are most boldly patterned in black and white, with striking green head colors. When the nesting season ends, the birds disperse over the vastnesses of the northern oceans, out of range of most human observers. Of the four species of eiders, the two most abundant and largest have circumpolar breeding distributions and extensive marine wintering ranges. These are the common eider, *Somateria mollissima*, and the king eider, *S. spectabilis*, whose flesh, eggs, and feathers have played a role in the survival of high-latitude human populations for thousands of years, and whose down has insulating qualities that are yet to be matched by artificially manufactured substitutes. The other two eider species are smaller and have much more restricted breeding distributions that center on the Bering Sea. These are the spectacled eider, *S. fischeri*,

by Paul A. Johnsgard

North American Molting and Wintering Migrations—King Eider



named for the gogglelike feathering pattern around its eyes, and the Steller's eider, *Polysticta stelleri,* named in honor of G. W. Steller, the naturalist on Bering's ill-fated expedition to Alaska.

Steller's eider breeds almost entirely in Siberia and winters primarily along the coastlines of the Aleutian Islands and in the vicinity of the Kamchatka Peninsula and the adjacent Kuril Islands. The spectacled eider, which nests commonly in some parts of eastern Siberia and in the Kuskokwim Delta of Alaska, seems to disappear into the open spaces of the Bering Sea every fall and is not seen again until the breakup of ice along the coasts of Siberia and Alaska the following spring.

It is the relatively sudden spring appearance of vast flocks of eiders, as the pack ice begins to break up near shore, that provides one of the intriguing aspects of these sea ducks. The flocks appear every spring at points and headlands along the western and northern Alaska coasts in numbers that are simply staggering. At places like Cape Romanzof and Cape Prince of Wales on the western coast of Alaska, flocks of eiders can be observed passing overhead in almost endless northbound streams between early May and early June.

On his trip to Alaska's Yukon-Kuskokwim Delta in 1924, naturalist Herbert Brandt watched the eider migration across Point Dall and Cape Romanzof. There the sequence of spring arrival was evidently associated with body size; the relatively large common eider arriving about the first week of May, followed in a few days by flocks of the king eider. The smaller spectacled eider and the Steller's eider followed in that order. One flight, predominantly of king eiders, began late in the afternoon of May 14, apparently continued all night, and persisted all of the next day. Brandt considered the number of birds passing over Point Dall and Cape Romanzof on May 15 as "beyond all comprehension." Nonetheless, he provided an estimate of 75,000 for a two- to three-hour period on that day. Essentially all of these were full-plumaged adult birds, indicating that as many or more first-year immatures must have remained at sea during the summer. The younger birds rarely come within sight of land until their second spring of life.

Colonies of common eiders nest among tussocks on coastal flats. The males leave the breeding area on their molt migration before the females finish incubating.

Olin Pettingill, Photo Researchers

At the time of Brandt's expedition, three of the four eider species nested in the vicinity of Hooper Bay, with the spectacled and Steller's eiders the most common. The Steller's eider has apparently ceased to breed in that vicinity, but the spectacled eider has remained common and this area is the center of the species' breeding range in North America.

On a visit to the Hooper Bay area in 1963, I observed that the spectacled eiders were nesting semicolonially, with nests often within fifty feet of their neighbors. Within a week or two after the females had begun their incubation, the males returned to the open sea. Based on observations by E. W. Nelson in the late 1800s, it is possible that the male North American spectacled eiders fly more than 200 miles north, to the vicinity of Norton Sound, in late June or early July to undergo a postbreeding molt.

All four species of eiders are known to undertake such "molt migrations," which can be of remarkable length. For example, a substantial number of male Steller's eiders from breeding populations in eastern Siberia have been banded at Izembek Bay, Alaska, where they undergo postbreeding molt. Some of these banded birds have been recovered from points as far away as the Lena Delta in Siberia, nearly 2,000 miles to the west.

Why birds would migrate so far prior to undergoing the physiological stresses associated with molting can only be explained if the destination offers an unusual degree of safety and food. This is indeed the case. The shallow and plant-rich waters of Izembek and Bechevin bays on the Alaska Peninsula provide an abundance of aquatic life sufficient to sustain some 200,000 eiders at one time. The molting Steller's eiders, which include not only males but also some females that presumably were unsuccessful in their nesting efforts, remain in the vicinity of Izembek Bay from fall through April.

The molt migrations of king eiders are also impressive. The North American population breeds along the northern coastlines of Alaska and Canada and falls into two groups: those that fly directly west across the north coastline of Alaska to a destination that is probably in the vicinity of Point Lay, about 200 miles southwest of Point Barrow, and those that fly almost directly east to the coast of Greenland. Virtually entire migratory flocks are composed of males, including both adults and immatures. The concentration off Greenland numbers several hundred thousand birds and includes all of the birds from Canada's eastern arctic, thus requiring a flight, in some instances, of more than 1,500 miles.

The king eider populations of Victoria Island and of Canada's western arctic may number at least a million birds. Nearly all of these pass by Point Barrow between mid-July and the end of August. This is evidently a migratory tradition of long-standing for among the most common weapons excavated at Point Barrow are 900- to 1,400-year-old Eskimo bone and ivory bola weights used in hunting eiders.

The first of the massive flocks to pass over Point Barrow in July is composed entirely of adult males; but

by mid-August there is a preponderance of unsuccessful female nesters. The later molting period of the females allows them more time to complete a nesting cycle. At least some of the adult females that succeed in hatching young do not participate in any of the major flights to the molting grounds; instead they remain until their young fledge in late August, then undergo their molt on the breeding grounds. By forming crèches, relatively few females are required to remain on the breeding grounds with the flightless young, thus freeing the rest for their molting migration.

After the adult eiders have finished molting, they again migrate. The eastern king eider population moves from western to southern Greenland and the coasts of Labrador and Newfoundland. The Alaskan birds move south to the Pribilof Islands, Saint Lawrence Island, and the Aleutian Islands where as many as a quarter-million birds may winter.

Little is known of common eider migrations in North America. In Scotland the movement from the breeding grounds to the molting area is only about 60 miles. In Norway there is enough topographic protection and available food in the breeding range to allow the completion of the flightless period there and no special molt migration pattern has developed.

While the eiders in Alaska are still on their nesting grounds, they suffer some depredations from humans. At Hooper Bay I often observed young Eskimo men collecting waterfowl eggs and hunting adult eiders with single-shot rifles. Herbert Brandt, talking of the same area, said that the skins of eiders and other ducks, and also those of geese, provided the favored linings for parkas, with the feathered side worn against the face. On Cape Dorset, Eskimo form organized egg-collecting forays to the colonies of common eiders, while women and children set up snares to capture nesting females.

In contrast to the harvesting techniques used in Canada and Alaska, the people of Iceland, Scandinavia, and Siberia have developed a tradition of eider "farming." In eider farming, down is collected intermittently during each nesting season, without destroying the nests or killing the females. When the female is approximately halfway through the incubation period there is a maximum amount of high-quality down present in the nest, and most of this can be removed without endangering the eggs. After the eggs have hatched, the remaining mixture of down and breast feathers can be gathered, although this collection is of second-quality and far lower commercial value. Roughly three-quarters of an ounce of high-quality down can be collected per nest, plus an equivalent amount of poorer quality down.

In Norway and Iceland the birds have been protected so long that they are almost domesticated. They are protected from predators and provided with specially prepared nesting sites. Colonies of more than 5,000 pairs have been developed under such conditions. On some eider farms the eggs are also taken from the first clutch, forcing the female to renest and produce a new clutch that she is allowed to hatch. In the USSR, eiderdown collection has been a part of the northern economy for centuries; seventeenth-century documents mention "bird down" among the goods sold to Dutch merchants. In 1930 about 1,000 pounds of down were obtained from Novaya Zemlya; on some protected areas of this archipelago, the density of nesting birds has been increased to as much as 13,000 nests per hectare (2.47 acres).

Once the birds have left their breeding grounds and moved to molting or wintering areas, their foraging activities and ecologic relationships become progressively obscure. The three larger eiders (genus *Somateria*) have virtually identical bill structures, which can be characterized as being relatively massive, with a broad and flattened naillike structure at the tip, much like that of their near relatives the scoter ducks. The larger eiders and scoters are known to feed predominantly on mollusks, particularly such bivalves as blue mussels, probably the single most important food of common eiders. King eiders also feed to a great extent on mussels, but are believed to forage in somewhat deeper waters and to utilize a greater proportion of echinoderms such as sand dollars and sea urchins in their diet. In spite of its lack of obvious streamlining or other diving adaptations, the king eider is able to dive to great depths to forage, reportedly as deep as 180 feet. This allows

Salt-excreting glands in the forehead of eiders (male king eider, right) are an adaptation for a marine existence.

the species to forage farther from shore than the other eiders or scoters and reduces foraging competition between them.

Far less is known of the foraging ecology of spectacled eiders in their wintering or migratory areas. Indications are that the spectacled eider also feeds on bivalve mollusks. Since it is scarcely seen near any coastlines in winter, the implication is that the spectacled eider must be able to dive to considerable depths in order to obtain its food.

The Steller's eider is known to forage in relatively shallow waters, often feeding while wading at the water's edge, dabbling like surface-feeding ducks. They evidently prefer soft-bodied crustaceans, such as amphipods and isopods, over mollusks, and in correlation with this, their bills have soft, membranous edges and an inconspicuous bill nail that is ill-suited to scraping bivalve mollusks off rocks. Consequently, the Steller's eider competes little for forage with other eiders.

The breeding biology, and molting and wintering migrations of the eiders have brought them into contact with man. To the people of the northern latitudes, eiders have been a valuable resource because of those characteristics of their life cycle that bring the birds in to shore. But more than any other group, eiders are sea ducks, and although not well known, the behavioral and morphological foraging adaptations of the four species illustrate the importance of the marine environment in their evolution. □

K. W. Fink, Bruce Coleman, Inc.

The Red Sea: An Ocean in the Making

by David A. Ross

Geophysical signs indicate that a new ocean is being born where the Arabian Peninsula and Africa are moving apart

According to the newest theory of geologists, the earth's crust is divided into a number of gigantic slabs of rock, or plates, that drift slowly but inexorably in different directions over the face of the earth, carrying the continents or ocean basins upon them. All the present continents of the world were joined together about 200 million years ago in one huge land mass, a supercontinent called Pangaea. Slowly, over the eons, Pangaea split apart into separate parts, or continents, which eventually moved to their present-day positions on the globe.

There are at least six major crustal plates today: the Pacific, American (including both North and South America), African, Eurasian, Indo-Australian, and Antarctic. Some of these can be subdivided into smaller plates for a total of almost twenty. Rigid and about 100 miles thick, the plates are moving in relation to each other. Their interior portions are more or less geologically quiescent, but at the boundaries where plates collide, mountain ranges are thrust upward or deep trenches are formed and earthquakes occur; where plates move apart, there is volcanic activity and new sea floor is created. About one square mile of new ocean floor is created each year and an equal area of trenches is consumed.

This theory of the earth, known as plate tectonics, presumes that the globe is in constant flux; that the continents are moving now, as they have done for hundreds of millions of years; and that new oceans are being opened by the process of sea-floor spreading, as continents formerly joined are slowly being separated. The Red Sea, although only a long, narrow strip of water, is thought to be such an ocean in the making. If the theory of sea-floor spreading is valid, it is probable that the Red Sea today resembles the Atlantic Ocean of about 200 million years ago.

The Red Sea is about 1,100 miles long, about 100 to 200 miles wide, and has a maximum depth of almost 10,000 feet. The sea is normally blue-green, but its northern end is occasionally populated by large-scale blooms of an alga that can color the water reddish brown, thus giving the sea its name. There is geologic evidence to support the idea that the Red Sea was formed by the moving apart of the Arabian Peninsula and the African continent, a process that began about twenty million years ago.

The topography of the Red Sea is distinguished by two major features: broad, rather smooth continental shelves and a deep, central trough, which is itself split by an even deeper axial valley that ranges from a few miles to about fifteen miles in width. The main trough and its axial valley extend almost the entire length of the sea, but at the northern extreme, near the Sinai Peninsula, where the sea forks into the Gulfs of Suez and Aqaba, the valley becomes difficult to detect.

By means of bottom photographs, drilling, coring, and a technique called seismic profiling, which depends on the reflection of sound waves from the bottom, charts of the underlying structure of the Red Sea and contour maps of its floor have been constructed. A series of bottom photographs made in the axial valley during a 1971 expedition to the Red Sea by a research vessel from the Woods Hole Oceanographic Institution showed numerous examples of recent volcanic activity, including small lava flows, which resemble toothpaste being squeezed out of a tube, and volcanic fissures and cracks. Layers of sediment are rare in the axial valley except in occasional small pockets.

The general absence of sediment in the valley is an interesting finding. Sedimentation rates in the rest of the Red Sea are about four inches per 1,000 years. If the axial valley had been in existence for say ten million years, then about 3,300 feet of sediment should be present in it. The records show no such thickness, although the rest of the main trough and the flanking shelf regions do show considerable amounts of sediment. This information suggests that the axial valley is a relatively recent feature of the Red Sea and has probably resulted from the process of sea-floor spreading. Additional geophysical

The near jigsaw puzzle fit of the shorelines is evident in this photograph of the Red Sea taken at an altitude of 151 nautical miles on the Gemini 12 *mission in 1966. Looking south from the Sinai Peninsula, the Gulf of Aqaba is on the left; the Gulf of Suez on the right.*

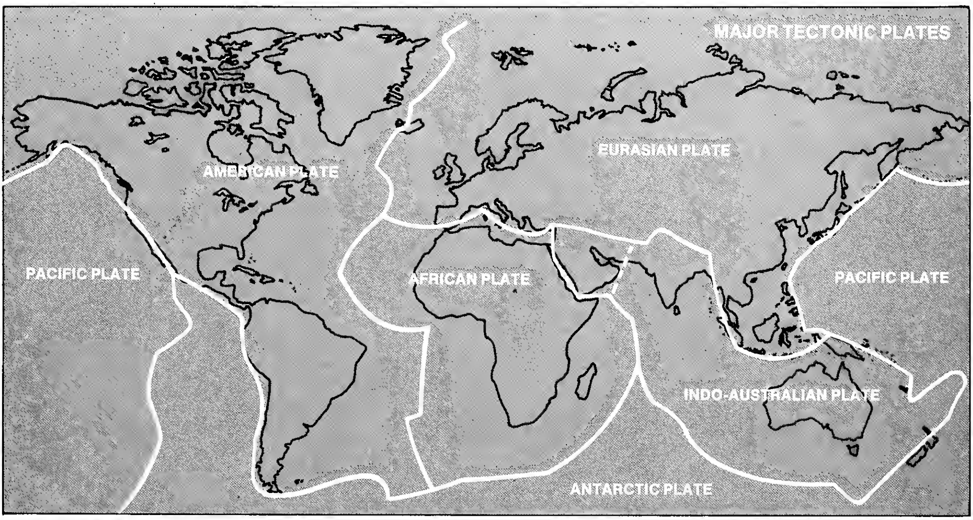
NASA

data also tend to confirm that conclusion.

First, there is a higher than average heat flow from the axial valley. This is attributed to the rise of deep, warm, subsurface material to the sea floor. Second, strong magnetic anomalies that are due to reversals of magnetic polarity have been found in the sea-floor material. As the lava rises to the surface in the axial valley and cools off, the magnetic minerals in it acquire an orientation parallel to the earth's magnetic field. Over the millennia, the earth's magnetic field has reversed itself on many occasions; a known timetable of those reversals, as determined from studies of land rocks going back many millions of years, can be used to deduce the ages of the sea-floor rocks. The character of the magnetic reversals found on the floor of the world's oceans can also indicate the rate of sea-floor spreading. In the Red Sea, the magnetic data clearly indicate a spreading rate of about one centimeter, or a little more than one-third of an inch, per year, that began about two million years ago. Finally, earthquake activity is relatively high along the axial valley. This, too, would be expected in an area where an ocean is being spread apart.

What appears to be happening in the Red Sea is that the Arabian and African plates are slowly moving away from each other. In that process, over the last two million years they have opened up the axial valley. A striking feature of the axial valley is that in certain bottom sites along its length there are pools of some of the hottest, most saline water found anywhere in the world. Temperatures of up to 140°F and a salt concentration of 256 parts salt to 744 parts water have been recorded in some pools. Ocean water salinity is typically about 35 parts salt to 965 parts water.

The hot brines found in the deep pools of the axial valley are considerably enriched in many heavy metals such as copper, lead, zinc, iron, and silver. The underlying sediments are also enriched in these metals. In one particular area, named the Atlantis II Deep for the Woods Hole ship that discovered it in 1965, these sedi-



The movement of global plates with respect to each other can produce several different effects at the plate boundaries. Where plates are moving away from each other, as in the North Atlantic, a gap is created in the ocean crust. Molten material rises from deep within the earth to form new sea floor within the gap—a process known as sea-floor spreading. The result is an ocean that is getting larger.

Where plates collide with each other and one plate includes an ocean basin, as along the western coast of South America, the ocean basin plate, being the heavier of the two, will be pushed under the continental plate. One result is a loss of sea floor and an ocean that is slowly narrowing. Another result is the formation of mountain ranges along the border of the continental plate.

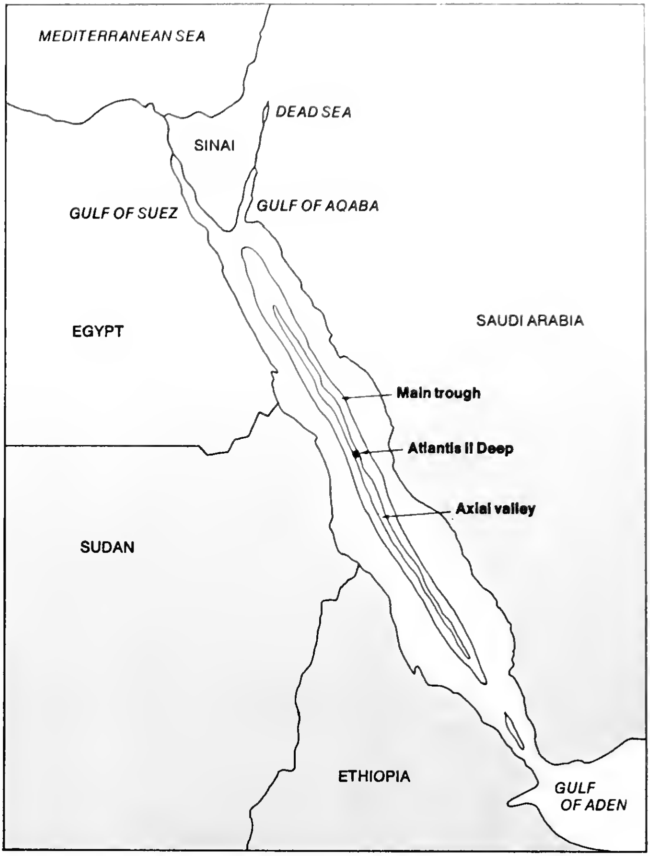
Where two plates are sliding past each other, shear zones of faults can be created. That is the origin of the San Andreas fault in California.

Several of these effects can take place simultaneously along different edges of the same plate. The Arabian plate, probably a subdivision of the Indo-Australian plate, is an example.

Where the Arabian plate is moving away from the African plate, which is assumed to be stationary, the floor of the Red Sea is spreading. Where the Arabian plate is being thrust under the Eurasian plate, in the area of the Zagros Mountains of Iran, sea floor from the Persian Gulf is being consumed. And where the Arabian plate is moving past part of the African plate, shearing is taking place in both plates.

ments have an in-place value of more than two billion dollars. Despite their value, it is possible that the metals may never be mined because the cost of raising the material from its depth about one mile below the surface of the sea and then refining it might be prohibitive.

The shelves of the Red Sea, unlike the axial valley, have been shown by seismic profiling to be underlain by a layer of rock, known as Reflector S, which is covered by several hundred feet of sediment. In 1972 the drilling vessel *Glomar Challenger* visited the Red Sea with two major objectives—to drill in the Atlantis II Deep area and to determine what Reflector S was. A total of three holes reached and penetrated Reflector S, and all of them showed it to be the top of a thick salt deposit that also included rocks, such as anhydrite, and other residues of evaporation. The sediments lying on top of Reflector S date back five million years. Although *Glomar Challenger* did not drill to the bottom of the reflector, its bottom has been reached by oil wells drilled on land where the deposit is almost two miles thick and from twenty-five to thirty million years old.



The vast accumulation of salt and anhydrite along the Red Sea bottom indicates that the sea must have been a shallow, high-salinity lake, perhaps like the Dead Sea or Great Salt Lake, for many millions of years. During that time there must have been occasional inflows of ocean water to replenish the water lost by evaporation and to enable the evaporation process to continue.

The layer of sediment overlying the salt deposit outside the axial valley (no salt was found in the axial valley) was found by seismic profiles to be of almost uniform thickness across most of the sea. Sediment can only collect where there is a surface for it to lie on. New sea floor, such as that being created along the axial valley, may be too young to have acquired a thick sediment layer. And, in fact, it does not have one. But old sea floor, formed earlier and then pushed aside as the floor spreads, should have tapering deposits of sediment that are thickest at the shoreline and thin out toward the axial valley. The finding of a uniform, rather than a tapered, layer of sediment on the subsurface salt deposit flanking the axial valley indicates that the spreading of the Red Sea has occurred in at least two stages: following the first, which began perhaps thirty million or more years ago, the thick evaporite sediments were deposited; during the second, which began about two million years ago and is still continuing, the axial valley opened up in the sea's main trough. No one knows why the sea-floor spreading in the Red Sea stopped or why it was resumed. Nor can anyone yet explain what causes the earth's tectonic plates to drift over the surface of the planet.

Geophysicists believe that phases of the history of the Red Sea probably mirror aspects of the early history of the Atlantic. About 200 million years ago, when the continents bordering the Atlantic were almost contiguous, as the shores of the Red Sea almost are today, the resultant body of water must have been long and narrow like today's Red Sea. Salt deposits found buried beneath the edges of the present Atlantic off the coasts of western Africa and Brazil, for example, indicate that evaporation must then have been high. And evidence of past heavy-metal deposits similar to those of the Red Sea's Atlantis II Deep have been found by deep drilling into the sediments of the continental rise off the east coast of the United States. It is therefore not unreasonable to suggest that the Red Sea is an embryonic ocean. If it continues to spread at its present rate, and there seems to be no reason why it should not, in a couple of hundred million years, even with possible future interruptions, the Red Sea could be as wide as the Atlantic Ocean is today. □

Red Tides

by Beatrice M. Sweeney

This unpredictable phenomenon of the sea, not really red or really a tide, is an ecological curse but often a visual delight

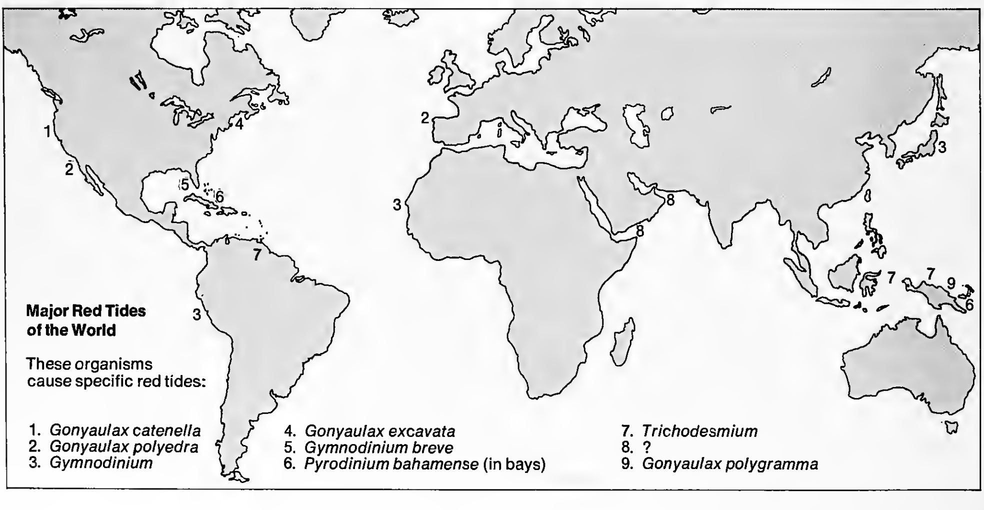
The plane lifts off the Los Angeles runway and as it banks around for the flight to New York, Santa Monica Bay comes into view. White sailboats dot the bay, but the water is not blue. It is pinkish orange. A "red tide." I am wondering how to describe the color as we fly eastward over the San Gabriel Mountains and on to the Mojave Desert. Does it resemble a sunset? tomato soup? blood? The yellow sand and the black lava flows below give way to the sunlit rocks of the Grand Canyon aglow in the morning sun. And there's the answer. The red tide is the exact color of the canyon's sunwashed rocks.

The red tide in Santa Monica Bay on this occasion was unusually extensive. More often, streaks or patches of reddish water are seen running parallel to the coastline. The edges of these patches can be remarkably sharp—so distinct, in fact, that from a small boat one can touch them with a finger. Even from high up, the patches of red tide are clearly visible. Infrared photographs taken from a U-2 reconnaissance plane flying at 65,000 feet show them quite well. In such photographs, filters are used that make the land appear a strange pink but show the sea and the red tide in their natural colors.

If a red tide is not a true red, neither is it a true tide. It has nothing to do with the rise and fall of the water level in response to the pulls of the sun and moon. A red tide is simply a streak or patch of water discolored by the presence of many small organisms of a single kind. Unlike true tides, a red tide is unpredictable, occurring in some years but not in others. It may be absent from a region for many years and then occur two years in a row. Along the coast of southern California, most red tides have occurred in late summer, in the warmest and calmest part of the year. Several recent red tides off Los Angeles have persisted well into the winter. A few days of high wind and rough water usually disperse them.

It is a fearful and mysterious experience to look oceanward and find that the blue sea to which we are accustomed has turned "red," a color we associate with blood, pain, and disaster. This frightening aspect may be why red tides have been recorded from ancient times. "All the waters that were in the river were turned to blood," we read in Exodus 7:20, an event interpreted as a punishment from God to Pharaoh, who would not allow Moses to leave Egypt.

Scientific records of red tides have been kept at Scripps Institution of Oceanography in La Jolla, California, since its founding in the first years of this century. These records show that this strange sea change is not new to the Los Angeles basin and



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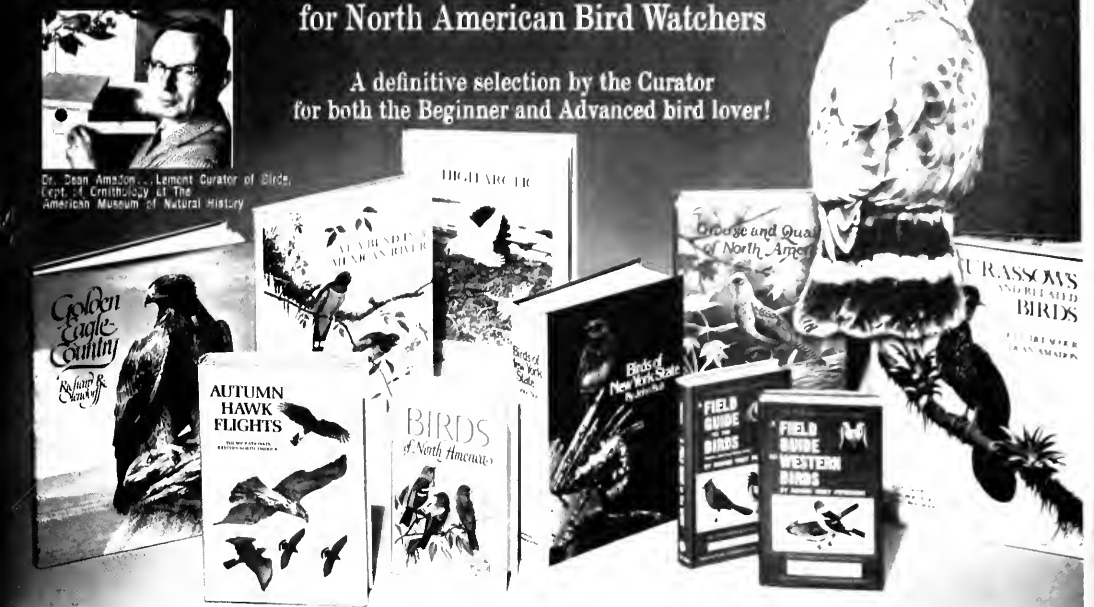

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is probably not associated with the great increase in population there and its attendant pollution.

What organisms make the sea turn red? If water is dipped from a patch of red tide and examined under a microscope, hundreds of single cells are seen swimming about in spirals. These unicellular forms of life are neither clearly plants nor clearly animals. Like plants, they have chloroplasts and are fully capable of manufacturing sugars by photosynthesis. But unlike terrestrial plants, they are orange or yellow rather than green. And like animals, these red-tide organisms can move about under their own motive power. The huge numbers of minute organisms, as many as a million in a quart of water, are what discolor the sea surface. Most of the organisms in any one red tide belong to a single species. That characteristic distinguishes red tides from the annual blooms of phytoplankton that occur regularly in many places each spring and consist of a mixture of different organisms.

Most red-tide organisms belong to one group of phytoplankton, the dinoflagellates, or "whirling whips." They all possess two flagella, or elongated appendages: one extending backward from a groove on the ventral side of the cell and capable of lashing from side to side; the other confined to another groove that encircles the equator of the cell. All the dinoflagellates that cause red tides are photosynthetic; they use visible light to convert water and carbon dioxide into oxygen and food, although other dinoflagellates do not have this ability and must live as animals do by ingesting other organisms. Many dinoflagellates are very beautiful, being decorated with horns and spines, frills and vanes. Members of this group are very common in the upper layers of the oceans where they constitute an important component of the total plant and animal plankton.

Red tides occur in many parts of the world. The most spectacular ones off southern California are caused by *Gonyaulax polyedra*, which has no common name. It is a roughly spherical, unicellular organism about 45 microns in diameter. By means of its two flagella, it can propel itself through the water at speeds up to 300 microns a second. There are a few cells of *G. polyedra* in the plankton during most of the year. In response to some as yet unknown combination of conditions, *G. polyedra* may begin to multiply, reaching more than normal numbers. At first, faint red streaks and patches can be detected near the shore parallel to the coast. As the days pass, the patches spread, moving considerable distances along the coast and becoming more intensely colored. They are most easily seen after the sun has been up for some hours. It is thought that during the day the cells swim upward toward the light at the water's surface and spread out or sink at night.

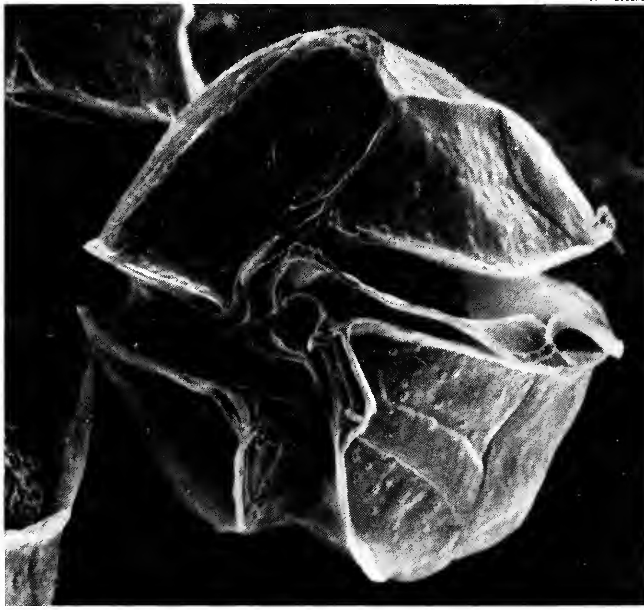
A few other species besides *Gonyaulax polyedra* cause red tides off southern California. One is a leaflike orange organism of the genus *Prorocentrum*. These two species account for almost all the red tides seen at Scripps since 1900.

Red tides seem to be more common along the west coasts of continents than off the east coasts, probably because those are the regions where seawater from the nutrient-rich bottom wells up to the surface. Red tides of *G. polyedra*, for example, have been recorded off the west coast of Portugal. The *Galathea* expedition, which sailed around the world in the 1950s taking plankton samples, found an unusually dense red tide off the west coast of Africa. *Gymnodinium*, the organism that caused this red tide, was so numerous that light penetrated only a few centimeters below the surface of the sea. *Gymnodinium* is also responsible for red tides off the west coast of South America.

The east coast of the United States was relatively free of red tides until quite recently. In 1972, however, a widespread red tide due to a species of *Gonyaulax* different from that off California, namely, *G. excavata*, appeared unexpectedly in the Gulf of Maine and extended south to Cape Cod. This happened again in 1974. Still another organism, *Gymnodinium breve*, has from time to time reached enormous numbers off the west coast of Florida, coloring the sea and producing devastating effects. And yet another unicellular organism, *Pyrodinium bahamense*, grows in large numbers all year round in certain enclosed shallow bays in the Caribbean islands and in New Guinea.

In the tropics, the sea surface often becomes streaked with red because of

Laurel A and Alfred A Loeblich



Gonyaulax excavata, *the organism from a 1972 red tide off Gloucester, Massachusetts, as photographed by scanning electron microscopy.*

the presence of an organism that is not a dinoflagellate, but a filamentous blue-green alga in which the red pigment, phycoerythrin, predominates. *Trichodesmium*, as this plant organism is called, floats in tangles on the calm tropical sea surface, the filaments sliding over each other in constant motion. There is evidence that *Trichodesmium* is able to fix atmospheric nitrogen, converting N_2, the inert form of nitrogen that makes up almost 80 percent of our atmosphere, to a form of nitrogen that can be used by organisms to synthesize amino acids. Lack of usable nitrogen is apparently the major bottleneck in the growth of the phytoplankton in many parts of the ocean. The phytoplankton is the food for all animals in the sea, directly or indirectly. Thus, red tides of *Trichodesmium* can be important in the economy of the tropical seas.

Whatever the cause of a red tide, its end may come about suddenly, precipitated perhaps by nothing more than a windy day. Sometimes all the cells in the tide lose their flagella and become resting cysts. Without flagella, the cells cannot swim. They then sink to the bottom and the red tide disappears.

Depending on the nature of the organism that has become plentiful enough to discolor the sea, red tides may have unexpected secondary effects. *Gonyaulax polyedra*, the southern California dinoflagellate, for instance, is able to produce flashes of light. When disturbed by the crashing of a wave or the quick motion of a fish, each cell emits a pinpoint of blue-green light. During a *Gonyaulax* red tide, this blue-green illumination traveling along a breaking wave is readily visible from shore on moonless nights. Moving through a red tide of *G. polyedra* by boat in the dark is an unforgettable experience. Illuminated fish tracks streak in all directions off the bow. Off the stern, the motor churns the water into a swirling mass of stars, sometimes bright enough to read by. This phenomenon is correctly called bioluminescence. At one time, it was mistakenly thought to be caused by phosphorus burning in the water and it is still occasionally referred to as "phosphorescence."

Gonyaulax excavata, of the New England red tides, is another bioluminescent organism. So is *Pyrodinium*, the "fiery whirler." The "Bays

of Fire" on the Caribbean islands of Jamaica and Puerto Rico have become tourist attractions because the brilliantly bioluminescent *Pyrodinium* grows there. Oyster Bay, on the north coast of Jamaica, where *Pyrodinium* can be found throughout the year, has served as a laboratory for the study of bioluminescence and of the conditions that favor the growth of this dinoflagellate.

The bioluminescence of large numbers of dinoflagellates in the open ocean at night was frequently noted by sailors in the past, before ships were illuminated by electricity. On dark nights it is still sometimes possible to see every wavelet flash light, a phenomenon described by Coleridge in "The Rime of the Ancient Mariner":

> About, about, in reel and rout
> The death fires danced at night;
> The water, like a witch's oils,
> Burnt green and blue and white.

Unfortunately, all the effects caused by the various dinoflagellates responsible for red tides are not as innocuous as bioluminescence. Several species of *Gonyaulax*—among them, *G. excavata* of the northeast coast of the United States, *G. acatenella* of western Canada, and *G. catenella,* common along the northwest coast of North America from Point Conception near Santa Barbara up to Alaska—manufacture one of the most toxic substances known. When filter feeders such as mussels and clams eat these organisms, they themselves are not generally harmed. The mussels sequester the toxin in their digestive glands, the clams sequester it in their siphons; the toxin accumulates in these storage depots and does not enter the cells of the shellfish. The shellfish themselves, however, become very toxic to any other animals that eat them, including humans. The poison affects the nerve cells and prevents the transmission of nerve impulses with fatal results.

On the West Coast, it is against the law to eat mussels during the summer months when *G. catenella* is common because of the danger that the mussels may have accumulated the dinoflagellate's toxin. The Alaskan butter clam cannot be used as food because the toxin is sequestered in its siphon. The poison that has been isolated from these clams has been designated "saxitoxin," after the mollusk's scientific name *Saxidomus giganteus.* Its chemical structure has recently been determined and the site of its devastating effects identified by experiment. The toxin blocks the action of the sodium pump of the nerves; this property may prove useful in the study of the transmission of the electrical impulse in nerves.

Point Conception, about midway between 34° and 35° north latitude, is the ecological boundary line between northern and southern California. It is there that the ocean current system changes. Although *G. catenella,* found north of the point, is toxic, *G. polyedra,* which causes the red tides in southern California, is not. Bioassays and chemical tests of extracts of *G. polyedra* have all been negative. It does not make saxitoxin. No deaths from eating toxic mussels have been recorded south of Point Conception.

The presence of toxin in *G. excavata,* however, proved a serious problem for public health authorities during the red tides off the coast of New England in 1972 and 1974. The fishing of clam and oyster beds is a lucrative business along the eastern seaboard. Nevertheless, it became necessary to close the shellfish beds and to post guards to prevent poaching of the clams and oysters that had become poisonous from the ingestion of the *Gonyaulax.* Because clams and oysters concentrate the toxin, shellfish can become toxic even before a red tide is noticed; therefore the monitoring of shellfish for toxicity became necessary. The process requires extracting the meat of the shellfish and injecting the extract into mice, an expensive and time-consuming procedure.

The story of the Florida red tides is altogether different. The *Gymnodinium breve* of that area produces several potent toxins as yet imperfectly understood with regard to structure or mode of action but highly poisonous to many kinds of fish. Unlike saxitoxin, the toxins of *G. breve* remain in the seawater and are taken in by fish. The result has been disastrous. Huge numbers of fish have died in the Gulf of Mexico along the southwest coast of Florida and have then been washed ashore, forming long windrows of corpses up and down the beach. When the dead fish decayed, the stench did little to encourage the Florida tourist industry. Worse yet, ocean spray containing the toxin blew ashore and humans who breathed this mist temporarily contracted sore throats, eye irritation, and sometimes, skin problems.

Red tides can be troublesome in yet another way. As long as the cells of the red tide are healthy, they give off more oxygen by day in photosynthesis than they consume at night in respiration. The oxygen concentration in the sea is high rather than low during a red tide. However, when the cells die for whatever reason, bacteria feed on them and multiply. When bacteria are very numerous, they deplete the oxygen in the water to such an extent that fish and other creatures die of asphyxiation. This occurs most dramatically when a red tide is washed into a shallow bay where conditions are unfavorable for the survival of red-tide dinoflagellates and where the volume of water is small and not flushed by the tide. Large numbers of fish have died under such circumstances, even when the red-tide organism was not a toxic one.

Despite considerable research on the conditions preceding and during an outbreak of red tide and on the physiology of dinoflagellates in general, very little is known about what causes red tides. We do know that with few exceptions only a single organism is responsible for any one red tide. This observation tells us that a general increase in the amounts of nutrients in the water cannot be responsible, for if it were, plankton organisms of many kinds would multiply, as they do in the ocean blooms of early spring. Is there a specific chemical substance that stimulates the growth of red-tide dinoflagellates to the exclusion of all other dinoflagellates? Why does one species gain a growth advantage over its close relatives? Why is it always the same species in a given location?

Special combinations of conditions, such as water temperature, water movement, and other unknown factors, must occur before a red tide can develop. What are these conditions? We do not know. In the sea, where water moves from place to place with the currents, it is difficult enough to locate the origin of a red tide, let alone detect the substances or conditions that are responsible in any one instance. Thus we cannot at present predict red tides with any reliability, although prediction would be most useful. Many questions must be answered before we can fully understand these tides. And without understanding, we cannot hope to control this mysterious mass production of organisms, at once beautiful and dangerous. □

Bounding the Main

by Warren S. Wooster

The negotiators at the Law of the Sea Conference are framing new rules to govern human activities in the world's oceans

The ocean covers most of the earth, and most of the ocean has been free—free for transit, free for fishing, free for research. But these freedoms of the high seas are being swept away in a frenzy of national seizures and international negotiations.

Since 1967, the United Nations has been attempting to legislate a new order in the ocean, initially in a long series of preparatory discussions, and since 1973 in the sessions of the Third United Nations Conference on the Law of the Sea (1973 in New York, 1974 in Caracas, 1975 in Geneva, 1976 in New York). The conference is distinguished by the number of negotiating countries (nearly 150) and by the breadth and intricacy of its agenda. Its task is complicated by the unilateral actions of impatient countries (for example, the recent U.S. declaration of a 200-mile fishing zone), by the rapid advances of technology, and by the political tensions among the western, eastern, and southern worlds.

Most of the new maritime issues have arisen since World War II. The ocean itself has changed very little in the intervening time. For the most part, its minerals lie untouched where they have rested for millennia. The fish gather, propagate, grow, and die in familiar neighborhoods. The ocean currents pursue their endless course, their temperatures changing only imperceptibly, if at all. Only in some of the fish stocks and around the edges of the ocean, in the estuaries and coastal waters are the harmful effects of human activities becoming conspicuous. More striking changes have taken place ashore—in the homes, factories, farms, laboratories, and legislatures of the world.

The steady increase in human population, particularly in coastal cities, has increased the demand for food of all sorts, including that from the sea. This has led to heightened pressure on fish populations, building up ever more rapidly as improved fishery methods are applied in grander and more systematic ways. The living resources of the ocean are threatened both by a more intense fishery and by degradation of their environment, not only in the coastal nursery grounds where urban development is particularly damaging but even in the open sea where pollutants transported by winds are deposited. Limitations are now evident in the capacity of the ocean's living resources to be exploited and of the ocean systems to absorb pollutants.

At the same time, fuels and minerals on land are becoming scarce. Alternative sources within and under the sea are being sought. Whereas jurisdiction of the coastal state over oil and gas deposits on the continental shelf is well established, it is not so clear who owns such deposits, if they exist, farther offshore on the continental rise. And the legal status of deep-sea mineral deposits, such as manganese nodules, remains to be established, this being one of the initial justifications for reopening the international debate on the law of the sea.

The role of the ocean in national security has also changed. Before and during World War II, the ocean was an operating theater and battleground for navies, but its larger strategic implications were limited to transport and communications. With the development of nuclear weapons and the concealment of the strategic deterrent beneath the ocean surface, the mobility and invisibility of missile-carrying submarines and their hunters have become matters of great concern to the superpowers.

As the uses of the ocean and its resources have grown and diversified, questions of jurisdiction and management of both resources and environment have become more critical. At the same time, there have been remarkable political changes that af-

fect intergovernmental negotiations.

The number of individual governments has nearly doubled since the last law-of-the-sea negotiations in 1960. Nearly all of the new countries can be classified as "developing," and they have found a natural affinity with other former colonies. The basic conflict of the present negotiations is between the "haves," mostly in the Northern Hemisphere, and the "have-nots" of the tropics and the Southern Hemisphere. Of course, the east–west competition remains, but on many maritime issues the United States and the Soviet Union have surprisingly similar interests and positions. The third world of relatively poor, nonindustrialized states has most of the votes, has a long memory of real or perceived abuse and exploitation by the former colonial powers, and is aware that these powers are now relatively impotent to force their will upon others.

Negotiations are complicated by other alignments. For example, there are 52 countries that have little or no coastlines or economic zones. These landlocked and geographically disadvantaged countries want access to the sea and to its resources, which will otherwise be gobbled up by the coastal states.

The political aspirations and attitudes of some 150 countries dominate present negotiations in the Law of the Sea Conference. If the process works, a comprehensive treaty will emerge to govern human activities in most parts of the world ocean. If agreement on a treaty proves to be unachievable, a chaotic world of unilateral action and reaction, and bilateral and multilateral accommodation, is likely to ensue.

What then are the major issues that affect the continued health of the ocean and man's continued enjoyment of the organisms that live within it? The issues of national security and commercial navigation (for example, passage through straits) are of major political interest, but the impact of these activities on the natural system

is relatively limited and indirect. All issues are affected by the mechanisms proposed for the settlement of disputes and the extent to which they are compulsory and apply to activities in the economic zone. But more significant for our purposes are the issues of protection of the marine environment, rational utilization of its living and nonliving resources, and the promotion of marine scientific research.

These issues are tied together by a new jurisdictional zonation in which the territorial sea expands from three to twelve miles, beyond which, stretching out to 200 miles from the coast, lies a new "economic zone," within which the coastal state controls the exploration and exploitation of all resources. Much of the debate has concerned the characteristics of this zone, whether it involves security or political jurisdiction as well as resource control, and the extent to which coastal-state jurisdiction will be shared with other nations.

How will the new law of the sea affect protection of the marine environment? First of all, despite the immensity of the ocean, most pollution originates on land, beyond the scope of an ocean treaty. The control of pollution is debated in many forums of which the sea law conference is only one. Secondly, the present negotiations are concerned primarily with jurisdiction, rather than management; the treaty, as it evolves, puts off definitive action, even on vessel-based pollution, for other negotiations.

Ocean-based pollution sources include deliberate ocean dumping and tank washing and inadvertent introduction from maritime activities. The former is already subject to regulation (which could be more effective), and until recently the latter has been relatively trivial. But the rapid development of continental shelf oil and gas production, the increased transport of petroleum products in supertankers, and the forthcoming exploitation of deep-sea minerals are likely to have major environmental impacts. The evolving treaty, by fixing jurisdictional responsibility for these activities, should make possible their eventual control.

Remember that environmental issues are often viewed differently by developed and developing countries. Pollution is a product of modern agriculture and industry. In their efforts to obtain a better life for their citizens, the developing countries wish to avoid the extra costs of environmental protection now considered unavoidable by their more affluent neighbors.

Who should have jurisdiction over the marine environment? The coastal, or port, state or the state under whose flag a vessel operates? The question is still unresolved. If the coastal state is to control living resources in the economic zone, it would seem appropriate also to control the environmental quality of that zone. Yet the arbitrary application of different standards from country to country could make navigation a nightmare. In any case, enforcement of environmental standards will be difficult. The flag state has the most control—yet in the eyes of the coastal state, it is least likely to exercise it in the interest of the environment.

Although jurisdiction over deep-sea mineral resources was the nominal reason for the present round of negotiations, fisheries on common property resources have more often led to international maritime conflict. Indeed, the important unilateral extensions of national jurisdiction in 1947 (Chile and Peru) were directly related to conflicts over the exploitation of whales and tuna.

Heretofore, living resources seldom confined themselves to the narrow territorial sea, and even a contiguous twelve-mile fishery zone was inadequate for comprehensive management of an entire stock. Since national jurisdiction was inadequate, regional and international bodies were established for management of one or another species. Occasionally these organizations have been effective, but as a rule their recommendations are difficult to enforce.

The purpose of management also has to be kept in mind. In the 1958 convention on living resources, achievement of the maximum sustained yield of a given stock was considered preeminent. Now it appears that other goals may be more important. In some cases, it may be better to maximize economic return; in others, the numbers of fishermen employed or the opportunities for recreation. Thus, it is now fashionable to speak of "optimum sustainable yields" without specifying which aspect is to be optimized.

The evolving treaty is concerned with several classes of fisheries with different jurisdictional implications. Sedentary species of the shelf, such as certain crabs and lobsters, were assigned to the coastal state by the 1958 convention. Most oceanic fisheries operate within a few tens of miles of the shore and will be managed by the countries whose economic zones are affected. Those resources that cannot be fully utilized by these countries could be shared with neighboring landlocked or geographically disadvantaged countries, on the one hand, and with countries that have historically fished in the region, on the other.

Anadromous species, principally salmon, may be caught offshore as well as in the economic zone of the host country in whose streams the fish return to spawn. It is generally agreed that such countries have both special responsibilities and special rights. The highly migratory species—tuna, billfish, oceanic sharks, whales, and porpoises—are widely distributed, and it is difficult to see how they can be effectively managed on a national economic zone basis.

The treaty may succeed in tying down jurisdiction over these classes of fisheries. But in most cases, effective management for whatever purpose will continue to require the collective action of the countries involved, both to determine the effect on the stock and to facilitate the application of measures to optimize whatever aspect of the fishery is mutually agreed upon.

Nonliving resources consist of those on the shelf, principally oil and gas, but also phosphorite, sand, and gravel, already under coastal-state control, and those lying beyond the shelf as defined in the 1958 convention, including the possibility of oil and gas on the continental rise and manganese nodules on the deep-sea floor. The new treaty will guarantee coastal-state control over seabed resources out to 200 miles, even for narrow shelf countries; that control may encompass the continental margin beyond 200 miles for the score of countries with broad shelves. This question of ultimate seaward extension and control over the continental rise (with some possibility of revenue sharing in this zone) remains unresolved.

The most hotly contested issue concerns exploitation of mineral resources—at present only manganese nodules are known to be important—beyond the limits of national jurisdiction. It was precisely these resources that Ambassador Pardo, in 1967, proposed should constitute the "common heritage of mankind,"

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Fish Market, The Bronx — Angel Soccodato

their benefits to be shared primarily among the developing countries

These nodules are seen as an important source of copper, nickel, cobalt, and manganese. Several factors contribute to their political importance—only a few of the most technically advanced countries command the capital and skill to exploit the nodules, and the metals that would thus be produced are major exports of several developing countries. It has already been agreed that an international body will manage the deep seabed; as a result of developing-country pressure, it also is likely to have the power itself to exploit the seabed and to participate in commodity agreements so as to protect the economic interests of land-based producers of the same metals. The developed countries, on the other hand, are seeking economic incentives and security for the vast expenditures required. It has not yet been demonstrated that nodule minerals can be competitive with land-based minerals, but the dependability of supply (lessened dependence on foreign suppliers) is likely to make the product attractive to U.S. consumers.

Design of the seabed authority and the division of power between industrialized and developing countries are major, unresolved issues. The developing countries constitute more than two-thirds of those participating in the negotiations, yet they recognize that no minerals will be raised from the depths (and no benefits therefrom will be distributed) without the participation of the few countries with the necessary technology.

Finally, the conduct of marine scientific research, both in the economic zone and beyond, has become an issue. Historically, there were no significant restrictions on research activities beyond inland and territorial waters until the 1958 convention on living resources gave the coastal state control over seabed research on the shelf. More recently, unilateral extensions of national jurisdiction have often included research. Today the draft treaty threatens to give coastal states complete control over scientific research in the economic zone, and there have even been serious proposals that research in the deep seabed should be managed by an international authority.

From the point of view of the government of a developing country, if resources of the economic zone are to be controlled, research relating to the

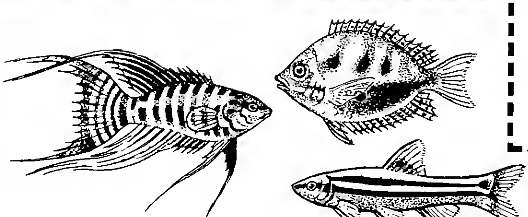
exploration and exploitation of those resources must also be controlled—and it can be argued that all research in one way or another has some relation to the resources in question. Otherwise, the scientist who conducts the research, and the government under whose auspices he works, may take advantage of the coastal state. Attempts have been made to distinguish between resource-related and "pure" research, on which fewer restrictions would be placed, but it is difficult to see how any objective operational definition can be found.

From the scientist's point of view, rational use of the ocean and its resources and protection of the marine environment are utterly dependent on improved scientific knowledge of the system. This is particularly true in the third of the ocean that lies within 200 miles of the coast, where most of the extractable resources appear to be located and where the impact of man's activities is greatest. And any impediment placed in the way of his investigation is likely to make it impossible to carry out. The scientist is fully prepared to share the information he obtains, although he recognizes that not everyone is equally able to understand and apply it.

Any meaningful sharing of information requires the evolution of comparable marine science capabilities in developing coastal states, accompanied by programs of realistic scientific collaboration among the scientists concerned. This is likely to lead to better science as well as to a more adequate sharing in the benefits of research. A section of the treaty is intended to facilitate this transfer of technology.

At the end of the spring 1976 session of the conference, progress had been made in the treatment of all these issues, but agreement on many of them continues to elude the negotiators. A final 1976 summer session will be held in New York, during which it should prove possible to reach a consensus. Otherwise, the opportunity for making sensible arrangements for effective use and protection of the ocean and its resources may be indefinitely lost.

Warren S. Wooster is Dean of the Rosenstiel School of Marine and Atmospheric Science at the University of Miami and has participated in the Caracas, Geneva, and New York sessions of the Third United Nations Law of the Sea Conference.



THE AMERICAN MUSEUM OF NATURAL HISTORY

Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun will move through the stars of Leo from about August 10 to September 16, then through Virgo till the end of October. This takes it gradually southward above the earth, bringing shorter days and a lower solar path each day. On September 22, when the sun arrives at the autumnal equinox, it will trace out the path of the celestial equator in our sky as it moves from due east, up to a point in the south equal to our distance from the pole, and then down to due west. The earliest navigators knew that they would arrive at the earth's equator when they could bring that line—the sun's path at the equinox—directly overhead.

We have an evening moon the first week of each month through October. Phases in August are: first-quarter on the 2nd, full on the 9th, last-quarter of the 17th, new moon on the 25th, and first-quarter again on the 31st. In September, full moon (the harvest moon) is on the 8th, last-quarter on the 16th, new moon on the 23rd, and first-quarter on the 30th. The hunter's moon (full) is on October 7. The moon is at apogee, farthest from earth, on August 16, September 12, and October 10; at perigee, nearest the earth, on August 27 and September 24.

Stars and Planets Altair, Deneb, and Vega, known to navigators worldwide as the Great Summer Triangle (although each is in a different constellation) dominate our summer sky nearly all night long these months (see Star Map, above the south). Venus will be an easily seen evening star, in the west each night for a short while after sundown. Jupiter is shown on the map where it rises in the east about midnight or earlier. It will be bright and high in the south at dawn. Saturn will be seen as a morning star in September, low in the east for a short while before sunrise.

August 10–13: These are the mornings, from midnight on, to look for the bright Perseid meteors. The morning of the 12th should be best.

August 17: Watch the moon slide from right to left past Jupiter tonight, from rising (shortly before midnight) until dawn.

August 23: The slender crescent moon may help you see Saturn, just to its left, about dawn this morning.

August 26–27: The crescent moon and Venus will make an attractive pair in early twilight. On the 27th, binoculars or a small telescope will help you find Mercury and Mars between the moon and Venus.

August 28: The moon occults, or covers, the bright star Spica for nearly an hour between 5:20 and 7:20 P.M., EST.

September 5: Mercury and Venus are in conjunction at 11:00 P.M., EST. They will be very close during early twilight, before they set.

September 10: Venus is in conjunction with Mars.

September 13–14: Jupiter rises with the moon several hours after dark on both nights, as the moon shifts from right to left below the planet.

September 19: Jupiter begins its retrograde, or westerly, motion. Watch it move to the right relative to nearby Aldebaran, in Taurus, and the Pleiades.

September 20: Saturn is near the moon this morning.

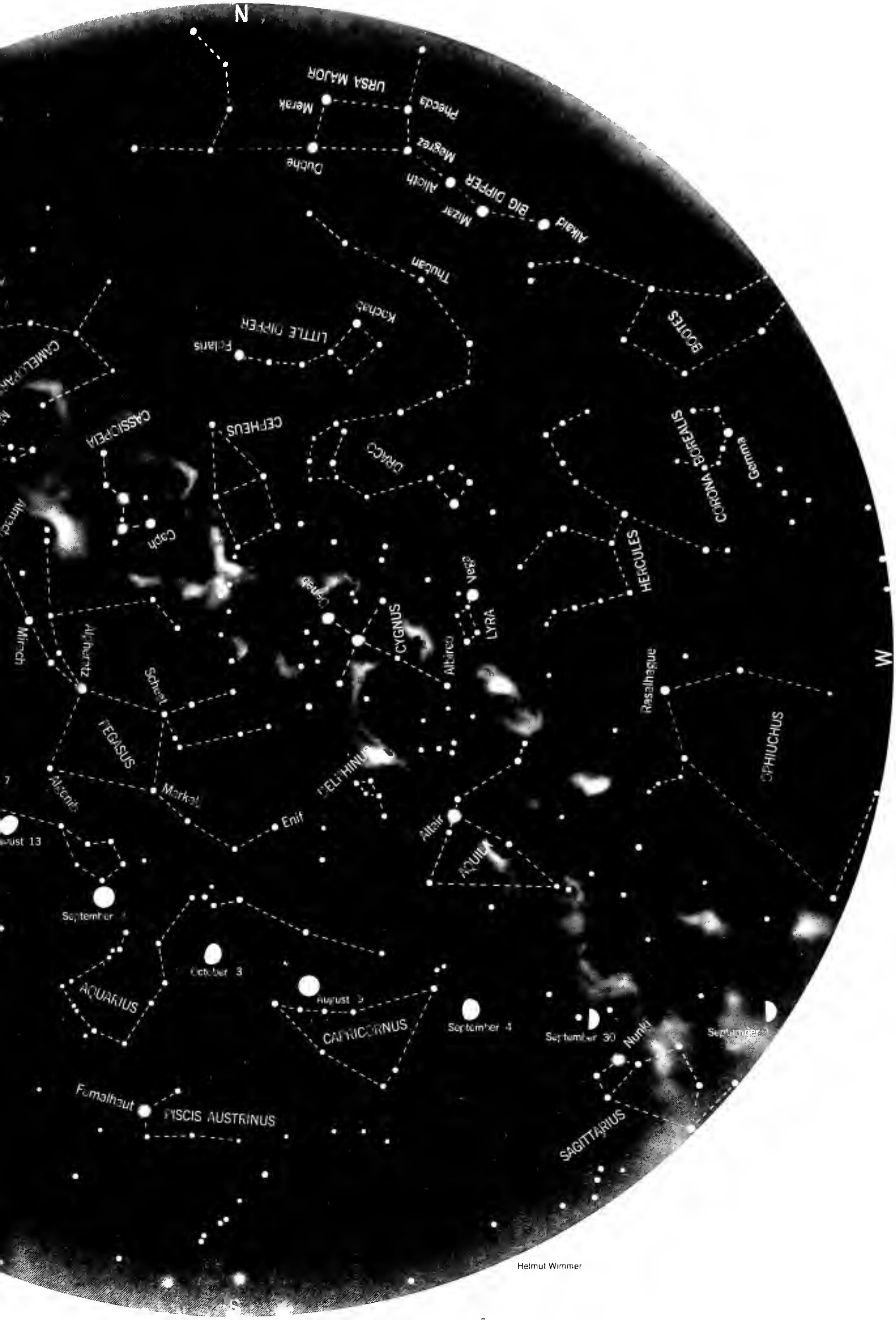
September 22: Autumn begins at 4:48 P.M., EST.

September 25: The moon is close to Venus early this evening.

October 7: Mercury is at greatest distance to the right of the sun, well placed in the east before sunrise, from the 1st to the 15th.

October 11: The moon will be very close to Jupiter tonight, moving away after 8:00 P.M., EST.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 12:20 A.M. on August 15; 11:20 P.M. on August 31; 10:20 P.M. on September 15; 9:15 P.M. on September 30; and 8:20 P.M. on October 15; but it can be used for an hour before and after those times.



Helmut Wimmer

The Net Result

In Laos, different varieties of fish, spices, and flavorings produce the "taste" of the culture

"If like myself, you take care to be provided with oatmeal wherever you go in the world, you will be able to split open a Pa mak pang, coat it with oatmeal and fry it thus in the Scots fashion," writes Alan Davidson, who is not kidding. He was her Britannic majesty's ambassador to Laos, the Land of the White Elephant. He is also an amateur ichthyologist and an epicure of the highest order. And during his tenure in Vientiane, his Excellency learned everything there is to know about the pa mak pang, a shadlike species (*Hilsa kanagurta*) of the Mekong, as well as other edible Laotian fish.

The main product of Davidson's studious ichthyomania, of his evidently ceaseless interrogations of fishwives in Luang Prabang and chefs at the Laotian palace, of his impassioned lucubrations in the piscatorial literature of Southeast Asia—the net result, you might call it, of all this research in a small but watery land—is a remarkable book. Davidson's *Fish and Fish Dishes of Laos*, printed, but not widely distributed, by the Imprimerie Nationale, Vientiane, in 1975, will put plenty of people to shame if it is ever published here. (The copy I saw was imported from Hong Kong by Sandra Faye Carroll, a Berkeley-based food writer who saw it in a bookstore and fell in love with Davidson's genial mixture of fish scholarship, anthropology, and culinary precision.)

For the first time, a native English speaker has translated the cuisine of a culturally remote country into usable language. This ought to have been one of the goals of anthropologists, who have spent so much energy and grant money cataloging other aspects of the material culture of distant peoples: their techniques for building homes or making up their faces. But there has been almost no anthropological field work done on cooking, although recipes are obviously significant artifacts of more than technical interest. They could even be used to reproduce the "taste" of an exotic culture on home soil. They are documents of universal appeal. They are dinner.

Food writers have also snubbed most of the world's cooks. Up until now, most foreign cookbooks (notable exceptions deal with western Europe, Hungary, Morocco, and Mexico) have generally been slapped together by writers who did not set down reproducible recipes, did not take care to identify unfamiliar ingredients so that a neophyte could lay his hands on them with certainty, and finally, did not set the food in context by explaining its place in the life and folklore of the people who normally ate it.

Ambassador Davidson has the advantage of a scientific bent and a compendious subject. He can cover a great many fish in close detail in a short space. And even if one never goes to Laos or hopes to, it is somehow life-enhancing to know, for instance, that the giant catfish pa beuk (*Pangasianodon gigas*) tips the scales at almost 700 pounds and may be the heaviest freshwater fish still catchable in the world's ever more fished-out rivers and lakes. It tastes like veal (so does sturgeon when sautéed in thin steaks). Its eggs, when salted, make a reddish caviar eaten on rice cakes at Luang Prabang.

With Davidson, we are always rooted in the savory realities of recipe, place, time, and custom. He does not merely state that pa kheng (*Anabas testudineus*) is a climbing perch that can walk and even climb out of water. He quotes an early description from a classic work and then adds: "One does not often find a fish up a tree (although it happens in Cambodia that, when the waters subside in the forests which are flooded annually some poor fish are caught in the upper branches of trees, whence fishermen can pluck them like fruit); and *Anabas* itself normally chooses to scale less dramatic heights." We then learn that, despite its bones, the *Anabas* is an important food fish, which is usually grilled or, for an elegant fish "tartare," you may follow directions from the Laotian Escoffier, Phia Sing, a polymath and chef, whose *cahiers* were lent by his widow and the crown prince of Laos to Davidson.

Phia Sing's recipe uses every part of the fish, as well as a most elaborate concoction of sauces, fumet, and herbs, of chili, ginger, and pounded eggplant. Indeed, Laotian fish cookery generally reflects the sophistication common to Thailand and Indonesia in the area of herbs and spices. The food is hot, but that hotness is skillfully varied with such flavorings as lemongrass, galingale, and Kaffir lime leaves (technically *Citrus hystrix*). These oddments are now available in New York and through the mail (see below). So it is possible to cook *à la laotienne*, especially if you have access to perch or catfish.

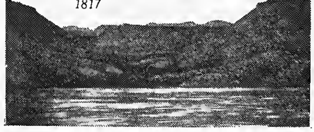
True, the difference in taste and texture between American and Laotian fish is probably noticeable, or would be if we could ever arrange for a blind tasting of fresh samples of both strains prepared in identical ways. This will not happen, I think, and so I will simply make the necessary substitutions, just as I do with sole (lemon for Dover) or bass (striped for loup de mer). At least, one can use the method of the country of origin. The difference is usually not unpleasant or a serious clash with authenticity.

These differences of taste between different varieties of similar fish and shellfish are one of the rewards of gastronomic travel. Fish change with the landscape while meat stays the same. I defy you to distinguish a pork chop raised in New York State from a pork chop fattened in Italy. A pig is a pig

is a pig (unless he is specially fed for prosciutto—but let that be). A salmon, on the other hand, pulled from Puget Sound in the spring and served in Seattle (preferably barbecued Indian-style with alder wood) tastes different from Scotch salmon or Alaskan or Scandinavian. Oysters from different spots on the Atlantic coast taste different from each other. Give me Chincoteagues every time, although I will gladly eat any old Bluepoint before downing one of those wretchedly bland west coast oysters.

Why should these undeniable variations occur? You may have already come up with a handful of explanations: different food sources, water temperatures, spawning opportunities. In other words, fish lead varied lives. Their environments differ. They are free of human management. Or, as D.G. Ginelly of the University of Kentucky put it in *Thailand, Inland Fisheries: An Overview* (quoted by Davidson): "Nearly all commercially important fish species are wild animals about which very little is known." Ginelly sees this as a disadvantage. He is thinking about fish as a protein source for a protein-hungry world. He, like other planners, would like to know why the crucially important giant herds of anchovy off the coast of Peru vanished anomalously not long ago and then came back in droves. This disappearing act left the producers of animal feed disastrously short of fish meal and helped to jack up the price of feed grains during the food-price crisis we have just weathered. The Dungeness crab has just made a similar comeback. We may hope that the apparently depleted haddock will follow suit.

Rapacious industrial fishing has already created scarcities of several species and has turned the once heroic life of the fisherman into an agribusiness of the sea. Waterborne factories are hunting down the diminishing cod, whose shortage provoked a diplomatic "war" over fishing rights in the North Sea. Meanwhile, in the Pacific, tuna fishermen are at loggerheads with conservation groups over how their particular fish hunt should be run. It transpires that the tuna fishermen want to continue to find tuna by following bellwether porpoises whose habit is to follow schools of prized yellowfin tuna. Conservationists claim that this dodge led to the "wanton slaughter" of 130,000 porpoises accidentally netted last year.



With this kind of fishlust on the high seas (and mariculture on an industrial scale already a fact of life even offshore of desolate French Guiana), you would think that we consumers were all as gung ho for fish as Ambassador Davidson and Souvanna Phouma. In reality, Americans dislike fish. They certainly will not, for the most part, touch eel, lamprey, or sea urchin eggs. All three—considered delicacies in France and other civilized places—thrive in American waters. Lampreys threaten whitefish in the Great Lakes. If only Michiganders would eat lampreys (*à la bordelaise,* in red wine), they would turn adversity into pleasure.

But the irony of fishing in America goes well beyond such marginal concerns. We are a nation fixated on red meat. We hold our noses at fish. In most places, specialized fish markets no longer exist. And supermarkets, when they sell fish at all, sell it frozen and cut into ugly little fillets made as unfishlike as possible.

Should you, nevertheless, come upon a passel of refrigerated but unfrozen whole fish, you can tell if they are fresh enough to take home by checking to see that the eyes are clear and bright, the gills red, the scales shiny and tight to the skin, and the flesh resilient to the touch and without a strong smell.

This is James Beard's standard operating procedure for buying any kind of fish. It guards against everything but pollution, about which we can only cry out in dismay and hope for the best. As a further sign of our faith and fervor for fish, we might also carry oatmeal everywhere and/or follow the custom of Lao women who wear the severed poisonous tail spine of the stingray (pa fa lai) in their hair as a "prophylactic against the Phi pop, or malign spirit."

Ken Som Pa

The fish soup of Laos, slightly adapted from Alan Davidson's *Fish and Fish Dishes of Laos.*

1 pound fresh fish (pa kho, the snakehead, is best, but any respectable freshwater fish will do)
2 or 3 stalks fresh, or 1 tablespoon dried, lemongrass (citronella)
½ teaspoon salt
½ teaspoon MSG (optional)
2 tablespoons nam pa (bottled Thai or other Southeast Asian fish sauce, such as nuoc mam from Vietnam)
1 large or 2 small tomatoes, quartered
3 scallions, both white and green portions sliced in thin rounds
2 tablespoons chopped coriander (cilantro or Chinese parsley)
Juice of ½ lime

1. Clean, scale, and wash your pa kho or other fish. Cut it into sections about one inch thick.
2. Crush the lemongrass stalks (or simply measure out the dried lemongrass) and combine with salt, MSG (if used), and 3 cups of water in a 3- to 4-quart saucepan. Bring to a boil, reduce heat, and simmer for 10 minutes.
3. Add the fish sections and the nam pa to the lemongrass broth. Return to the boil, add tomato quarters, reduce heat, and simmer gently for 10 to 15 minutes uncovered.
4. Take the soup off the fire. Remove and discard the lemongrass stalks (it is not possible to remove the dried lemongrass fragments unless you take the precaution of tying them up in a cheesecloth bag before immersion, this is perhaps an excessive refinement).

5. Garnish soup with scallion and chopped coriander.
6. Put a few drops of lime juice in each soup plate. Pour the soup in, making sure that each plate receives its share of fish, tomato, scallion, and other solid ingredients. Stir and eat.

Note: Davidson does not indicate how many people he serves with this quantity of soup. My own feeling is that four people will fare quite well with the amount indicated if a full meal is to follow. The exotic ingredients were all available at Thailand Food Corporation, 2445 Broadway, New York. In other cities, a Thai or Indonesian restaurant should be a useful source. Filipino markets sell fish sauce under the name patis. Dried spices can be ordered by mail from H. Roth and Son, 1577 First Avenue, New York, N.Y. 10028.

Variations

1. In the south of Laos, tamarind leaves or pulp are often added when the cooking is nearly finished. If you do this, do not put lime juice in the soup plates.

2. At Luang Prabang, and in the south, too, chunks of pineapple core may be used instead of tomato quarters. This is very economical. The rest of the pineapple will serve as dessert. But the core has relatively little flavor; I recommend the modest extravagance of using some of the pineapple flesh in the soup. Another expedient, useful when tomatoes are not at their best and mangoes are in season, is to substitute pieces of green mango for the tomato.

3. Those who like fiery dishes will add to this soup whatever quantity suits them of freshly ground chili.

4. Some Lao cooks add to the water, along with the crushed lemongrass stalks, one or two "fingers" of fresh ginger and half a dozen slices of galingale root (sold in the United States as "laos"), both of which have previously been roasted in the oven or over charcoal. These are later discarded with the lemongrass, but they leave behind them a subtle flavor, which does not overpower the soup but greatly enhances it. I warmly recommend this variation, worth executing with the ginger alone if galingale is not at hand.

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*

Creatures from the Primordial Seas

TRILOBITES: A PHOTOGRAPHIC ATLAS, by Riccardo Levi-Setti. *University of Chicago Press, $27.50; 213 pp., illus.*

Fewer than 10 percent of all known forms of life inhabit the marine environment. This statistic surely reflects the fact that we ourselves are land-living creatures, biased in our interests and modes of perception. It is far easier for us to trap mammals and fruit flies than to sample the mollusks and ophiuroids living on the floor of the abyss. Yet the statistic is probably on the right order of magnitude; despite our still-primitive deep-sea sledges, dredges, and underwater photographic techniques, there really do seem to be fewer kinds of marine than terrestrial organisms.

On the other side of the coin, of the twenty-three or so known animal phyla, only three (arthropods, mollusks, and chordates) have fully terrestrial members; all of the rest of the phyla are restricted to moist, if not entirely aquatic, environments—and most of them are restricted to marine habitats. The oceans are rich in terms of the variety of major groups of animals, but relatively poor in species.

Most of us do not live near the sea. Those of us who do may be familiar with some of the invertebrates in the intertidal habitats—rocky intertidal, quartz sand beaches, and intertidal mudflats. Skin divers may learn what the shallow subtidal fauna is like, fishermen haphazardly examine life in the deeper waters of the continental shelf, but only the biological oceanographer can get a glimpse of life off the shelf—down the continental slope, on the abyssal floor, and in the deep oceanic trenches.

Yet we are all basically familiar with the many forms of oceanic life.

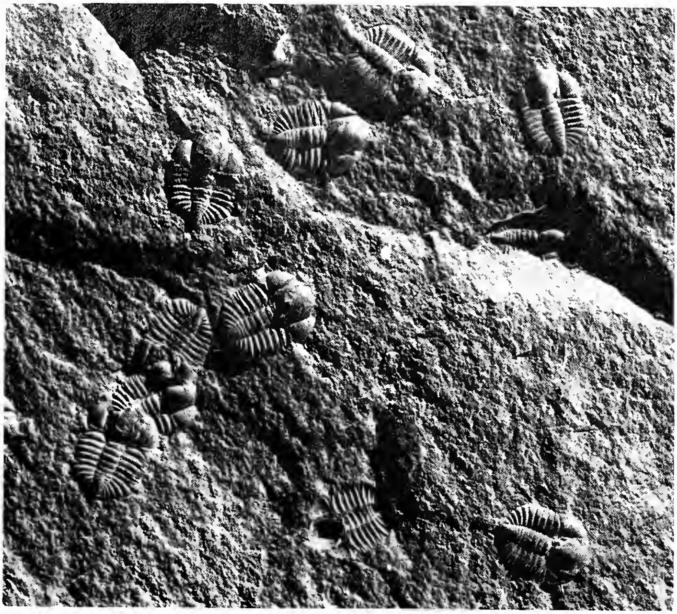
Phacops rana crassituberculata

by Niles Eldredge

Even living far from the sea, most of us know what oysters and crabs look like. We know about them from seafood markets, textbooks, and picture books. And shell shops have distributed hundreds of thousands of specimens into the hands of collectors.

Readers of Stephen Jay Gould's column in this issue will learn about, or be reminded of, the antiquity of the invertebrate biota of the world's oceanic system. Almost since its inception some 600 million years ago, the basic flavor of multicellular animal life in marine environments has remained essentially the same. The

Ampyxina bellatula



constituent species have changed, to be sure. And some major groups have disappeared along the way, while new ones have appeared. Advanced crustaceans such as crabs and lobsters are now with us, while their more primitive arthropod cousins, the trilobites, are totally gone—unless one day we dredge one up from some deep-sea trench, a fantasy still lurking in the back of the minds of some paleontologists and marine biologists I know. But the basic pattern has remained the same: all the phyla we now find in the oceans were present in the Cambrian.

But how do we flesh out a mental picture of these long-gone denizens of the deep? Are we to be satisfied with a mere enumeration of species in Cambrian and younger seas? What, exactly, *is* a brachiopod or a trilobite?

In a way, we can actually examine the remnants of ancient marine life more easily than we can experience the ins and outs of modern marine life. Fossils abound by the trillions all over the continent. Almost every state in the union has produced

marine fossils. The limestone quarries, roadside outcrops, stream banks, and railroad cuts of the American Midwest everywhere expose rocks formed from the hardened bottom sediments of ancient seaways that periodically inundated our continent. The skeletons of countless organisms are lying in these rocks, and pretty much in their original condition, just where they were left millions of years ago. However, relatively few books on fossils are available that are comparable in scope and grandeur to some of the magnificent photographic atlases of living invertebrates (particularly mollusks). Now at last we have a book that reveals in exquisite detail and admirable depth the nature of what, to my prejudiced mind, is the most fascinating of all forms of ancient life: the trilobites. In 158 beautiful photographic plates, Levi-Setti has produced a work of intrinsic esthetic charm and valuable information. I use this book not only for my own enjoyment but, even more, to convey to friends what I actually do for a living.

The classification adopted in the book is unconventional. Developed recently by Jan Bergström of Lund, Sweden, the classification contains so many debatable points, as yet not fully thrashed out by the scientific community, that its use in this book is premature. My other reservation is the heavy coverage accorded the most common United States genera and species: *Elrathia kingii, Phacops rana,* and the various virtually identical species of *Flexicalymene* are overrepresented, although Levi-Setti points out that perhaps they deserve such emphasis merely because they are so common. I would have preferred to see more of the rarer elements of the trilobite fauna.

Trilobites appeared early in the Cambrian, and breathed their last sometime in the Upper Permian period. Thus the Paleozoic era, nearly 400 million years in duration, can virtually be defined in terms of the stratigraphic range of the class Trilobita. This extraordinary group of primitive arthropods deserves wider appreciation, and I can think of no better way to find out more about them than to purchase a copy of this book, open it up, and just drink in page after page of pure trilobites.

Niles Eldredge is associate curator of invertebrate paleontology at The American Museum.

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Additional Reading

Ocean Currents (p. 30)

Joseph L. Reid's "Deep Ocean Circulation" (pp. 203–17) in *Oceanography: The Last Frontier*, edited by Richard C. Vetter (New York: Basic Books, 1973, $11.50), adds to our understanding of the interactions between oceanic and atmospheric circulation. *Oceanography: Readings from Scientific American*, edited by J.R. Moore (San Francisco: W.H. Freeman, 1969, $4.50), includes the September 1969 issue—ten articles devoted to the ocean, such as R. W. Stewart's "The Atmosphere and the Ocean"—as well as a number of earlier pieces, such as Walter Munk's "The Circulation of the Oceans" and Henry Stommel's "The Circulation of the Abyss." The first six chapters in Stommel's *The Gulf Stream: A Physical and Dynamical Description* (Berkeley: University of California Press, 1965, $10) are a good introduction to the subject of North Atlantic currents. Comparable discussions of the North Pacific are found in *Kuroshio: Physical Aspects of the Japan Current*, edited by Henry Stommel and Kozo Yoshida (Seattle: University of Washington Press, 1972). Susan Schlee's *The Edge of an Unfamiliar World* (New York: E. P. Dutton, 1973, $10.95) presents an informal history of oceanography as a human endeavor—the people, ships, politics, and science of the seas since the early 1800s. For a nontechnical account of the tools and techniques of the science, see G. L. Pickard's *Descriptive Physical Oceanography* (Elmsford: Pergamon Press, 1964, $3.50).

Deep-Sea Fishes (p. 38)

Deep-Water Fishes of California, by John E. Fitch and Robert J. Lavenberg (Berkeley: University of California Press, 1968, $2.25), a paperback field guide to deep-water fishes of the eastern Pacific, gives detailed life histories of representative species. Many libraries will have a copy of *Aspects of Deep-Sea Biology*, by N. B. Marshall (London: Hutchinson, 1954), one of the first overall treatments of deep-water biology. Marshall presents animal and plant life histories, the interrelationships of animals with each other and their habitats, problems of sampling and studying anatomical and physiological adaptations (bioluminescence, special sensory systems), and dozens of color paintings and drawings. Included in Peter J. Herring and Malcolm R. Clarke's collection of papers on general oceanography, *Deep Oceans* (New York: Praeger Publishers, 1971), are N. B. Marshall's "Animal Ecology" (pp. 205–24) and J. A. C. Nicol's "Physiological Investigations of Oceanic Animals" (pp. 225–46). Paul A. Zahl's "Fishing in the Whirlpool of Charybdis" (*National Geographic*, 1953, vol. 114, pp. 579–618) provides some of the first photographs of deep-sea fishes of one area of the Mediterranean, where upwelling currents bring such deep-water animal life near the surface.

Sea Otters (p. 46)

"Recovery of a Fur Bearer" (*Natural History*, November 1963, pp. 12–21) and "Return of the Sea Otter" (*National Geographic*, 1971, vol. 140, pp. 520–39), both by Karl W. Kenyon, an authority on this fascinating mustelid, are well-illustrated introductions to sea otter biology and behavior. Kenyon's 350-page definitive study of *Enhydra lutris*, "The Sea Otter in the Eastern Pacific Ocean" (*North American Fauna*, 1969, no. 68), has recently been republished as an inexpensive paperback (New York: Dover Publications, $4). Adele Ogden's recently reprinted (1975) *The California Sea Otter Trade: 1784–1848* (Berkeley: University of California Press, 1941) is a detailed survey of the exploitation of this once important fur bearer. George and Ellen Laycock's photographic essay *The Flying Sea Otters* (New York: Grosset & Dunlap, 1970) deals with the reintroduction of captured sea otters to parts of their former range on Alaska's Pacific coast. *The Sea Otter in Eastern North Pacific Waters* is a compilation of recent information by Alice Seed (Seattle: Pacific Search, 1972, $1.75). For a thorough account of the sea otter's prey, see E. F. Ricketts and J. Calvin's *Between Pacific Tides* (4th ed. Stanford: Stanford University Press, 1968). James A. Estes and John F. Palmisano's article in *Science*, "Sea Otters: Their Role in Structuring Nearshore Communities" (1974, vol. 185, pp. 1058–60), gives more technical details of their work.

Lobster Tales (p. 60)

William F. Herrnkind's articles, "Mi-

gration of the Spiny Lobster'' (*Natural History*, May 1970, pp. 36–43) and ''Strange March of the Spiny Lobster'' (*National Geographic*, 1975, vol. 147, pp. 819–32), contain fine photographs and accounts of adult behavior in the Caribbean species. *Octopus and Squid: The Soft Intelligence*, by Jacques Cousteau (Garden City: Doubleday, 1973), is a good introduction to the characteristic behavior of octopods, a major predator of spiny lobsters. A rare, but classic, work on *Homarus americanus*, is F. H. Herrick's monograph-length study, ''Natural History of the American Lobster'' (*Bulletin of the U.S. Bureau of Fisheries*, 1911, vol. 29, pp. 149–408). Harold B. Clifford's *Charlie York: Maine Coast Fisherman* (Camden: International Marine Publishing, 1974, $7.95) tells the story of the lobster from the point of view of the lobsterman, spinning a tale of the disappearance of plentiful lobsters and a way of life centered in their harvest.

Eider Ducks (p. 68)

Compilations of eider biology are found in Paul A. Johnsgard's *Waterfowl of North America* (Bloomington: University of Indiana Press, 1975) and Frank Bellrose's new and extended version of F. H. Kortright's classic (1942) *Ducks, Geese and Swans of North America* (Harrisburg: Stackpole Books, 1976, $12.-95). Both give accounts of each species, summarizing their biology, ecology, and behavior, but Bellrose presents additional quantitative data on population densities and migratory activities. Wildlife biologists Daniel Q. Thompson and Richard A. Person document a late summer molt migration in ''The Eider Pass at Point Barrow, Alaska'' (*Journal of Wildlife Management*, 1963, vol. 27, pp. 348–56). A description of a spring migration of eiders in the 1920s is provided by naturalist Herbert Brandt's classic volume, *Alaska Birds Trails: An Expedition by Dog Sled to the Delta of the Yukon River at Hooper Bay* (Cleveland: The Bird Research Foundation, 1942). David Munro discusses commercial exploitation in ''The Eider Farms of Iceland'' (*Canadian Geographic Journal*, August 1961, pp. 3–9).

Red Sea (p. 74)

An inexpensive introduction to the complex processes of sea-floor spreading and plate tectonics is *Continental Drift: A Study in the Earth's Moving Surface*, by Don and Maureen Tarling (Garden City: Doubleday, 1971, $1.95). Two other readable but more detailed accounts are *Continents in Motion*, by Walter Sullivan, science editor of the *New York Times* (New York: McGraw-Hill, 1974), and *Debate About the Earth*, by H. Takeuchi et al. (San Francisco: Freeman, Cooper & Co., 1967). For articles dealing with rift systems and relative motions of continental plates, see ''Plate Tectonics of the Red Sea and East Africa,'' by D.P. McKenzie et al. (*Nature*, 1970, vol. 226, pp. 243–48); ''The Afar Triangle,'' by H. Tazieff (*Scientific American*, vol. 222, no. 2, pp. 32–40); ''Plate Tectonics,'' by J. F. Dewey (*Scientific American*, 1972, vol. 226, no. 5, pp. 56–68); and ''Rifting in the Okavango Delta,'' by Christopher H. Scholz (*Natural History*, February 1976, pp. 34–43). T.D. Allen and C. Morelli's ''The Red Sea,'' in *The Sea: Ideas and Observations on Progress in the Study of the Seas* (vol. 4, pt. 2, pp. 493–542), edited by Arthur E. Maxwell (New York: John Wiley & Sons, 1970), is the most complete treatment of the area's topography, geology, and oceanography.

Red Tides (p. 78)

Proceedings of the First International Conference on Toxic Dinoflagellate Blooms (1974), edited by V.R. LoCicero, is available from the Massachusetts Science and Technology Foundation, 10 Lakeside Office Park, Wakefield, MA 01880. Representative papers are: ''Red Tides I Have Known,'' by Beatrice Sweeney (pp. 225–34), and ''The First 'Red Tide' in Recorded Massachusetts History: Managing an Acute and Unexpected Public Health Emergency,'' by W. J. Bicknell and D. C. Walsh (pp. 447–58). ''Red Water in La Jolla Bay, 1964–1966,'' by plankton biologist Robert W. Holmes et al. (*Limnology and Oceanography*, 1967, vol. 12, pp. 503–12), describes a series of California red tides. An article for the general audience is: ''Poisonous Tides,'' by S.H. Hutner and J.J.A. McLaughlin (*Scientific American*, 1958, vol. 199, no. 2, pp. 92–98).

Gordon Beckhorn

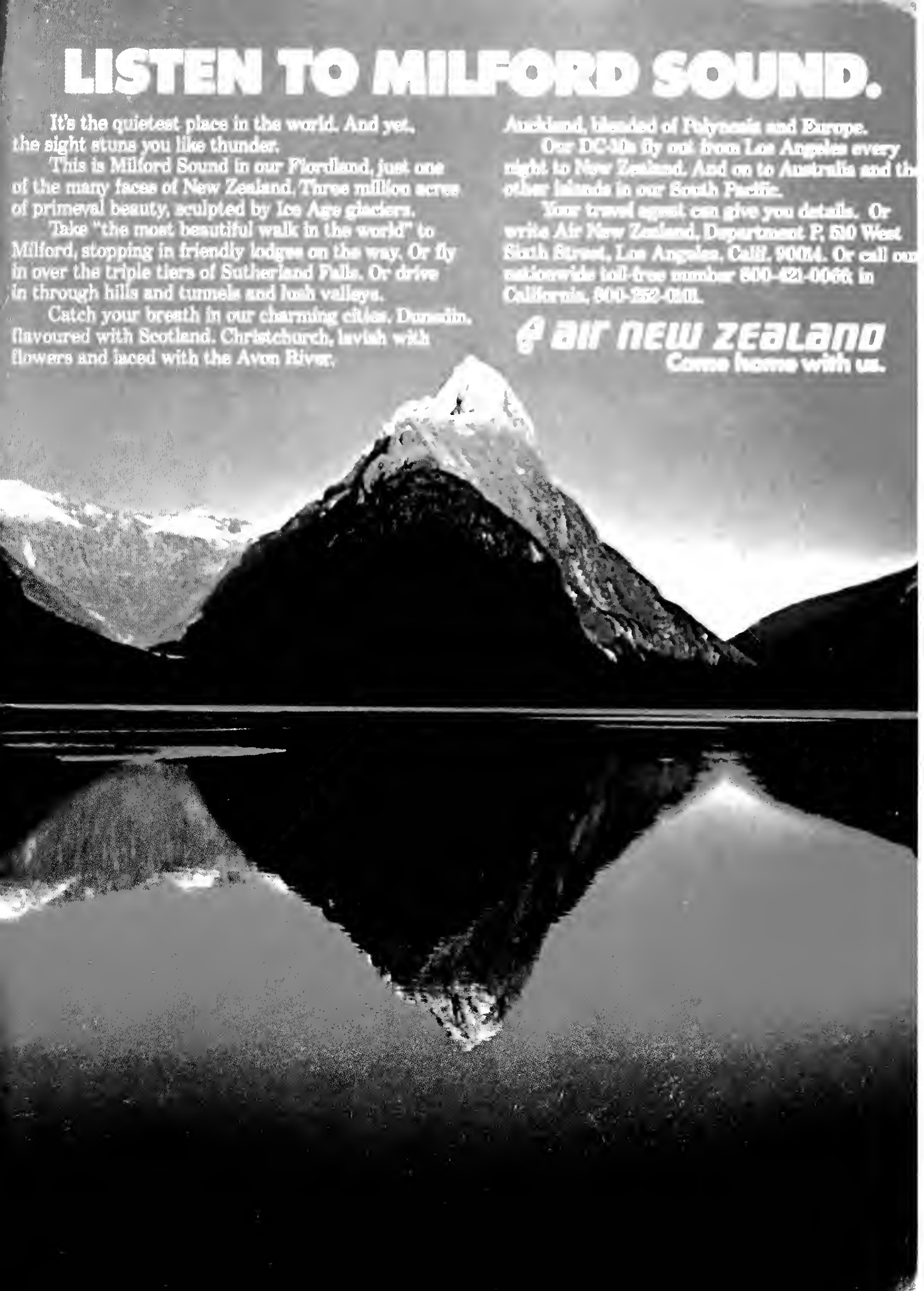
Announcements

A new permanent hall—**The Hall of Minerals and Gems**—is located in the southwest corner of the first floor of The American Museum of Natural History. This is a most spectacular and elegant hall, with an impressive array of minerals, gems, rocks, and meteorites. It is the largest in the Museum and covers such major subjects as properties of minerals, mineral-farming environments, systematic mineralogy, interaction of minerals and energy, and esthetics of gems.

Acoustiguide Tours—Dr. Vincent Manson, consultant, Department of Mineral Sciences, is your guide on a tour of the new Hall of Minerals and Gems; Dr. Thomas D. Nicholson, director of the Museum, directs you to the highlights of the Museum's exhibitions; Dr. Margaret Mead takes you through the Hall of Peoples of the Pacific; Dr. Eugene Gaffney travels back in time via the dinosaur halls; and Dr. Dean Amadon guides you on a worldwide ornithological tour. All Acoustiguide Tours can be rented for a nominal fee at the Information Desk on the second floor.

At the **Hayden Planetarium** of the Museum, "Yankee Stargazers" will continue through September 27. This show recounts contributions by Americans to the knowledge of the universe—from the first astronomical observation in the New World (in 1494) through New York physician Henry Draper's photographing the sky in the mid-1800s, Karl Jansky's discovery of radio waves coming from space in 1932, man's landing on the moon in 1969, and the first landing on Mars in the summer of 1976.

"Follow the Sun" opens on September 29 and will continue through November. This Sky Show explores the nature of our nearest star, its source of energy, the changes it undergoes, some of its influences on earth, and its place in the universe. Shows begin at 2:00 P.M. and 3:30 P.M. on weekdays with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children and students (special rates for groups and senior citizens).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October 1976

The American Museum of Natural History
Robert G. Goelet, President
Thomas D. Nicholson, Director

Cover: *The Hamadryas baboon is vulnerable to extinction because of its large body size, limited geographic range, large home range, and specialized habitat. Photograph by Bruce Coleman, Inc. Story on page 90.*

Publication Office: The American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Published monthly, October through May; bimonthly June to September. Subscriptions: $10.00 a year. In Canada and all other countries: $12.00 a year. Second-class postage paid at New York, N.Y. and at additional offices.

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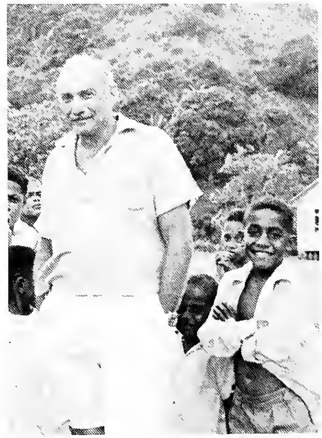
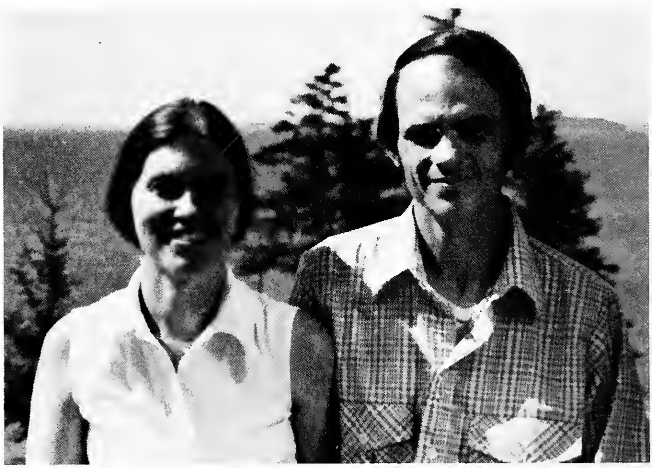
Authors

"At some period in our lives," writes **Robert S. Desowitz,** "those of us engaged in research on disease raise our eyes from the microscope to view the world around us." Desowitz, who had spent twenty years studying parasitic infections in Africa, Southeast Asia, and the South Pacific, became interested in the ecology of disease when he undertook epidemiological investigations in South Vietnam. These studies were part of the report prepared by the National Academy of Sciences Committee on the Effect of Herbicides in South Vietnam. Desowitz is currently professor of tropical medicine at the University of Hawaii, where he is studying the immunological aspects of malaria.





Interested in the problems presented by island faunas, **Kenneth L. Crowell** began studying the birds of Bermuda as part of his doctoral research more than fifteen years ago. Since that time, he has investigated competition between two species of flycatchers in the Caribbean and has visited the islands of Maine's Penobscot Bay, where he researched the dynamics of mouse populations. His article "Down East Mice" appeared in the October 1975 issue of *Natural History.* Crowell, who teaches at St. Lawrence University, makes his home in northern New York State. His wife, coauthor **Marnie Reed Crowell,** is a writer whose works include *Greener Pastures,* a description of life on their farm, and *North to the St. Lawrence,* a history of upper New York.

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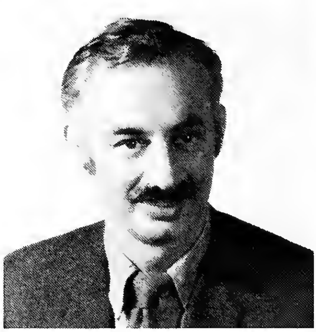
While studying primates, **Jaclyn H. Wolfheim** began to suspect that many species were in danger of extinction. Few zoologists were working on the problem, so in collaboration with the World Wildlife Fund and the U.S. Fish and Wildlife Service she compiled data on the status of each primate species for use as a reference work for scientists. She has plans to study the composition and population density of African forest monkeys and the effects of logging on these primates, many of whom are threatened. A lecturer in biology at George Mason University in Fairfax, Virginia, Wolfheim received a Ph.D. in zoology from the University of California at Berkeley.

A native Canadian who admits to an unprofessional love for the high country, **William G. Wellington** has found an ideal outdoor laboratory in the mountains of western Canada. There, he combines his interest in insect behavior and ecology with meteorology—investigating the reactions of insects in all kinds of weather conditions. Director of the Institute of Animal Resource Ecology at the University of British Columbia, Wellington has not forgotten the human animal: he is now studying ways in which cloudy regions of mountainous recreational areas might be transformed into fly-free zones.

When **Ralph Mitchell** sees an oil slick on the water, he is likely to take samples of the nearby flora and fauna to determine if they are diseased. Usually they are, a finding that helps him pinpoint his research on how low-level oil pollution affects microbial processes. Mitchell's initial research involved corals in laboratories at the Woods Hole Oceanographic Institution and at Harvard University, where he teaches environmental biology. Those studies led to work on coral reef systems in both Bermuda and the Red Sea. Mitchell now plans to use his knowledge of microbial processes to study the effects of pollution on fish species. **Hugh Ducklow,** a graduate student in biology at Harvard, is studying the microbiology of coral reefs.



Ill-Nourished Brains

Will the world's 400 million malnourished children suffer permanent intellectual retardation?

Juan, a small, puffy child, sits on the dirt floor of his one-room house in a rural village in Mexico. He stares blankly at the wall, no longer crying or complaining about the pain in his stomach. He is cold and weak and doesn't move. Although five years old, he is only three feet tall and weighs about thirty pounds.

Halfway across the country, five-year-old José runs with his friends to an open lot where they find an old junked car. They look inside. One boy discovers the latch to the hood and José opens the hood and peers curiously inside. He then slips down to look under the car. While his friend turns the steering wheel, José watches the rods push the front wheels from side to side. He traces the movement back to the steering wheel. José smiles, for now he has some understanding of how a car works. He cannot wait to tell his father and to come back to the lot the next day.

Juan, like the majority of children in the world, perhaps more than 400 million, suffers daily from the pangs of hunger and malnutrition. Worse yet, Juan's encounter with severe malnutrition may cause permanent damage to his brain, leaving him unable to ever reach his intellectual potential. Because of this horrifying possibility, many government officials, public health workers, physicians, nutritionists, psychologists, and other scientists have been working together to answer some basic questions concerning the long-term intellectual and behavioral consequences of childhood malnutrition. Does malnutrition produce permanent brain damage? Does malnutrition produce mental retardation? If malnutrition does affect intellectual development, what are the brain mechanisms responsible and are the changes reversible?

Direct answers to these questions are difficult to determine and would require a rigorous scientific study, including long-term observation of children who are clinically malnourished and not receiving treatment. Clearly, such a study is, and must remain, ethically impossible. Although an indirect approach has limitations and requires considerably more effort to reach a sound conclusion than a direct one, we have learned a great deal not only about the long-term consequences of early malnutrition on cognitive development, but also about the brain's development, vulnerability, and functioning.

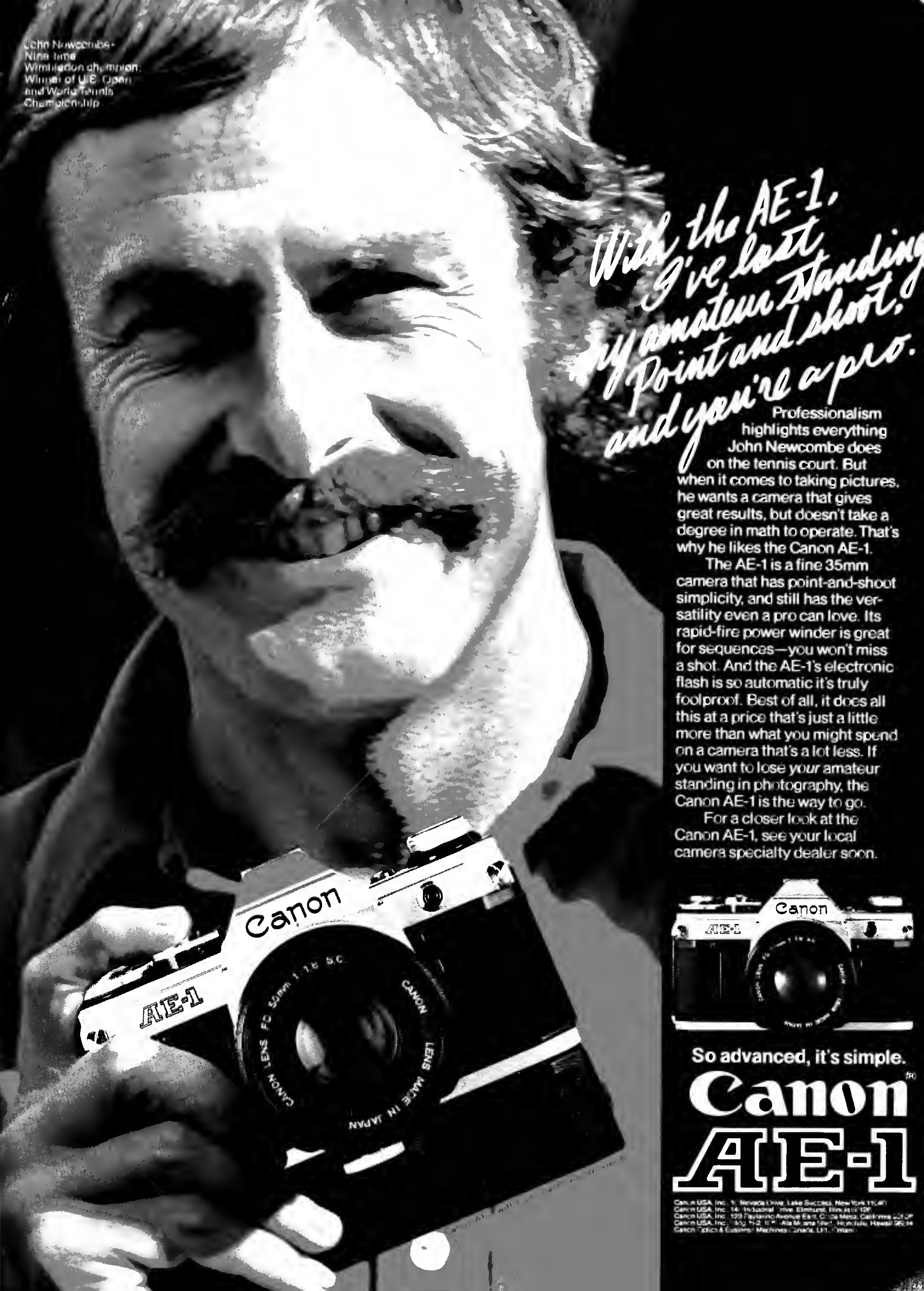
The idea that the brain may be affected by malnutrition is relatively recent. Early in the history of nutrition, at about the turn of this century, the brain was thought to be "spared" from nutritional insult. Scientists came to this conclusion because the brain, unlike other organs of the body, maintained its weight and composition during the course of nutrient insufficiency. Not until the early 1960s did scientists—working in South Africa and South America—find that children suffering from protein-calorie malnutrition showed signs of delayed cognitive development as measured by standard intelligence and developmental tests. Although the tests were refined to remove cultural bias, persistent lags in cognitive development prevailed in children who had suffered from early malnutrition.

Most noticeable was delayed language development. Age of speaking, vocabulary, and language organization are all deleteriously affected by protein-calorie malnutrition. Tied to retarded language development were delays in intersensory integration—the ability to pair a particular visual shape, such as a letter, with its particular sound. The development of intersensory integration is essential for learning to read. These studies, then, contradicted the earlier notion that the brain was spared from the deleterious effects of malnutrition. Behaviorally, these children showed the effects of malnutrition through alterations of brain function.

At about the same time, researchers working with laboratory animals found that the animal brain was indeed "vulnerable" to periods of severe malnutrition, particularly during the phase of rapid brain development—the first two or three years of life in a child or the first few weeks of life in the case of laboratory animals. They found that the brains of animals malnourished early in life were smaller and contained less DNA. Total DNA is taken as an index of the total number of cells of the brain. Most importantly, even following long periods of nutritional rehabilitation, the brain remained smaller and the DNA content lower.

Was this true also of humans? Unfortunately, it appears so. Children who have been malnourished show smaller brains, containing less DNA, than normal children. Thus, by the late 1960s the findings were fairly clear and very grim: children who suffered from malnutrition had smaller brains and also displayed signs of retarded cognitive development as measured by various developmental tests. The next question, Are these independent effects of malnutrition or does the physical change in the size of the brain produced by malnutrition cause the cognitive retardation? then became terribly important. If the brain is irreversibly altered by early malnutrition, then one must expect that generations of adults, perhaps entire societies, will perform at a suboptimum intellectual level. This would be catastrophic for developing countries trying to make technological leaps in a few decades and requiring highly specialized learning. These nations, of course, are the very ones suffering the ravages of malnutrition.

It thus became crucial to understand how malnutrition affects cognitive development. Since we cannot



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BY CADILLAC

measure the biochemical and neurological events taking place in the brain of a developing child, we had to develop an animal model of cognitive development. At least in animals we can investigate the changes that take place in the brain during and following severe malnutrition.

But how was one to use the animal as a model for the cognitive development of humans? To study this question, Richard H. Barnes, a nutritionist working at Cornell University, brought together a number of psychologists, physiologists, biochemists, and nutritionists. The early findings of this multidisciplinary research group were clear. Rats subjected to severe protein-calorie restrictions early in life and then nutritionally rehabilitated over a period of several months still showed depressed performance in learning difficult discrimination problems. But the researchers, aware that many factors can affect learning performance and that differences in learning performance do not necessarily mean differences in the ability to learn, were cautious in interpreting their results.

When I joined Barnes's research staff in 1968, we conducted several studies that clearly showed that early malnutrition in rats and pigs increased their emotionality, again following nutritional rehabilitation. This is particularly true when the animal is placed in a situation that evokes an emotional response. Its reaction to a loud noise, a new environment, or a mild electric shock, for example, is greater than that of the well-nourished rat. The animal may squeal more, defecate or urinate, show reluctance to enter a novel environment or to return to one in which it was frightened.

This increased emotionality following malnutrition occurs in many different kinds of situations and in several different species, two factors that are crucial if we wish to use the laboratory animals as models for humans. The effects of malnutrition on behavior seem to hold for a variety of mammalian species, including rats, pigs, mice, cats, dogs, and monkeys. Interestingly, protein-calorie malnourished children are also highly irritable and susceptible to temper tantrums.

But to return to our original question, Does early malnutrition permanently impair the brain so that it cannot learn, that is, process cognitive information? In carefully controlled experiments neither we nor any other group has demonstrated any deficit in the ability of either a previously or currently malnourished animal to learn. Does that mean that early malnutrition does not affect cognitive development in animals or man? Not necessarily; it may mean that malnutrition affects cognitive development through mechanisms other than the ability to learn in typical learning situations.

As mentioned previously, one of the long-term behavioral effects of early malnutrition in animals is a heightened behavioral reaction in any emotion-evoking situation. Other conditions will produce similar effects, one of the most powerful being environmental isolation. Raising rats, mice, dogs, monkeys—or humans—in isolated environments produces long-term changes in behavior that can be observed in the adult. In all these cases there is an increase in behavioral reactivity to emotion-provoking events.

One explanation of this behavioral effect was offered by Ronald Melzack of McGill University, who theorized that the young mammal is continually learning about its environment in order to react appropriately to it. Our reaction to a novel stimulus is typically associated with an emotional response; we fear what we have never experienced. To the adult animal reared in isolation almost everything is novel and hence it displays exaggerated emotional responses in far more situations.

What is important to us is the concept that the young organism is continually learning about its environment, not because the experimenter forces learning, but because it naturally occurs. Since the effects of early malnutrition and early emotional isolation produce similar behavioral effects, is it possible that both conditions, seemingly quite different, are operating through similar mechanisms?

In an experiment with rats, we raised groups for the first seven weeks of life under three sets of conditions: (1) standard laboratory environments; (2) environmentally restricted environments in which the animals were raised in small lightproof, soundproof chambers; and (3) environmentally "stimulating" environments in which the animals lived with littermates, were handled regularly, and had access to toys and other objects. In each of these three condi-

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tions there were two groups: one fed an excellent quality diet; the other maintained on a very low protein diet. Thus, all nutritional and environmental manipulations occurred during the first seven weeks of life. We then gave all animals a regular diet and placed them in standard environmental conditions for ten weeks before giving them a series of behavioral tests.

The results clearly showed the profound effect of early environment on many different behaviors. The previously malnourished animals were hyperexcitable, moved about in short, quick movements, were more aggressive, engaged in more fights, and were more reluctant to enter a large open area. More important, while early environmental isolation exaggerated these effects, environmental enrichment almost completely eliminated them. Poorly nourished animals raised in a stimulating environment tested almost as well as those that were well nourished.

These results raise some important questions concerning the mechanisms through which malnutrition may affect cognitive development. As far as can be determined, the effect of environment on brain growth is extremely small compared to the effect of early malnutrition. The brain size as well as total DNA content of the brains of all the malnourished animals were not significantly affected by environmental conditions, although their behavior was dramatically affected by their environment. Thus, even if malnutrition leads to the reduction in the size of the brain or possibly the number of neurons, this does not seem to be the major cause of the behavioral abnormalities.

This is not to say that the differences in behavior do not have a physical substrate in the brain. Indeed, there are differences in enzymes necessary for the metabolism of acetylcholine, a brain neurotransmitter, which correlate with the behavioral effects of the nutrition–environment interactions. Rather, the reduction in the brain size or total number of brain cells does not appear to be the critical variable in the production of behavioral abnormalities, and the ability of the animal to learn is not affected by severe malnutrition.

In order to reconcile these results and still explain the long-term behavioral abnormalities of animals malnourished early in life, we developed the concept of "functional isola-

tion." The young organism is constantly learning information about its environment through play, curiosity, and exploration. This internally motivated curiosity to learn, however, is inhibited by malnutrition; the organism becomes "functionally isolated" from the acquisition of certain kinds of environmental information. Thus, malnutrition early in life may affect cognitive development, not by damaging the brain's capacity to learn, but by producing behaviors incompatible with normal environmental learning. The group of malnourished rats upon whom we "forced" environmental stimulation displayed only a minimal residual effect of malnutrition. When the information of the environment was minimal, however, malnourished animals were much more severely affected, behaviorally, than the well-nourished controls raised in isolation.

How does malnutrition "functionally isolate" the young organism from certain aspects of environmental information? One of the most obvious ways is the delay of psychomotor development. The young malnourished child or animal, late in developing the coordinated movement necessary for crawling and walking, cannot explore its environment. Also, malnutrition restricts environmental learning through its action on the mother. Young rat pups that are malnourished either prenatally or postnatally are smaller and less developed in motor skills. The rat mother, reacting to these pups as if they were younger, has increased contact with them through the course of lactation. During the latter part of this period, pups normally attempt to leave the nest and explore their environment, but as a result of their smaller size, delays in their psychomotor development, and increased contact by the dam, such exploration is delayed.

These effects of malnutrition on the young and on the behavior of the mother also occur in humans. Dr. Alfonso Chavez of the National Institute of Nutrition in Mexico has studied the home environments in a rural Mexican village where the rate of malnutrition in children is quite high. Two groups of children were matched for physical, social, and economic characteristics of their parents. One group received a small food supplement, starting during the mother's pregnancy and continuing for the first three years of the child's life. During this time carefully trained observers,

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well acquainted with the villagers, went into the homes and studied the child and family for several days at a time throughout the three years of the study.

The children receiving no supplemental food spent more time in the crib, slept more, spent less time out of the home, and were much more "attached" to their mothers than the supplemented group. The children receiving additional food, being more active, demanded more social interaction from the parents and siblings and thus induced an increase in the level of "cognitive stimulation" in the home.

Another mechanism through which malnutrition may affect cognitive development is through a depression in the young mammal's delightful curiosity. We are all aware of this behavior in the young puppy, kitten, or child. Parents know that a child may be getting sick because he is not as playful as usual. This playful curiosity is extremely susceptible to nutritional and physiological status; protein or calorie restriction profoundly alters the tendency of a young animal to explore a novel object placed in its environment. Experimenters have seen this with young rats, pigs, and monkeys, and clinicians frequently note it in malnourished children. While recuperating in hospitals, these children commonly sit quietly in the corner of a playroom filled with toys, rarely touching or trying to work any of them. They lack the curiosity-induced learning essential for environmental learning and for maximizing their cognitive potential.

These concepts help to explain a long-perplexing issue: why malnutrition has a greater effect on children from countries that are less technologically and economically developed than on those from affluent nations. In fact, studies of children from wealthy countries show no permanent effects of early malnutrition on cognitive development. During the Dutch famine winter of 1944/45, when the Germans blocked all ports, many infants in The Netherlands were severely malnourished. Yet this did not adversely affect their intelligence, according to later studies. Similarly, a group of middle-class children studied in Boston, malnourished because they suffered from cystic fibrosis, which impairs nutrient absorption, did not show permanent signs of intellectual impairment.

The environmental setting of the children during the time they were malnourished is obviously important. Both the Dutch and Boston children were raised in highly educated societies. Even during the war years in Holland, there was strong emphasis on education. The Boston children did not suffer from a lack of intellectual stimulation. Like the laboratory situation in which the malnourished rats were forced into a stimulating environment, these societies encourage, indeed require, learning. They do not have to rely on endogenously motivated curiosity.

One of the most encouraging aspects of this problem is the possibility of rehabilitating the previously malnourished child. If the functional isolation model is correct, we are not talking about a permanently damaged brain or impaired ability to learn. Making the child well again should rekindle the curiosity to learn; at that time, he can begin to recover the accumulating store of cognitive information lost during the period of malnutrition. Myron Winick of Columbia University has recently accumulated some evidence to support this. Studying orphaned Korean children who were malnourished early in life, rehabilitated, then raised by American adoptive parents, he found no impairment in their IQs. Of course, "learning resources"—schools, teachers, books, involved parents, and a society that encourages learning—must also be available.

One cannot talk about malnutrition and intellectual development without talking about the total environment of poverty. The economics of poverty robs the child of good schools, attractive toys, libraries, books, and educationally stimulating environments. Poverty robs the parents of the time they can devote to playing with their children and "intellectually stimulating" them. But of all the ills of poverty, malnutrition is perhaps the cruelest, for it robs the child of one of the most precious characteristics of the young—and possibly one of the most important for the ultimate attainment of his intellectual potential—the hunger to learn.

David A. Levitsky, who has conducted numerous studies on the relationships between nutrition and behavior, teaches in the Division of Nutritional Sciences and the Psychology Department at Cornell University.

Darwin's Untimely Burial

Despite reports to the contrary, the theory of natural selection remains very much alive

In one of the numerous movie versions of *A Christmas Carol*, Ebenezer Scrooge, mounting the steps to visit his dying partner, Jacob Marley, encounters a dignified gentleman sitting on a landing. "Are you the doctor?" Scrooge inquires. "No," replies the man, "I'm the undertaker; ours is a very competitive business." The cutthroat world of intellectuals must rank a close second, and few events attract more notice than a proclamation that popular ideas have died. Darwin's theory of natural selection has been a perennial candidate for burial. Tom Bethell held the most recent wake earlier this year in a piece called "Darwin's Mistake (*Harper's*, February 1976): "Darwin's theory, I believe, is on the verge of collapse. . . . Natural selection was quietly abandoned, even by his most ardent supporters, some years ago." News to me, and I, although I wear the Darwinian label with some pride, am not among the most ardent defenders of natural selection. I recall Mark Twain's famous response to a premature obituary: "The reports of my death are greatly exaggerated."

Bethell's argument has a curious ring for most practicing scientists. We are always ready to watch a theory fall under the impact of new data, but we do not expect a great and influential theory to collapse from a logical error in its formulation. Virtually every empirical scientist has a touch of the Philistine. Scientists tend to ignore academic philosophy as an empty pursuit. Surely, any intelligent person can think straight by intuition. Yet Bethell cites no data at all in sealing the coffin of natural selection, only an error in Darwin's reasoning: "Darwin made a mistake sufficiently serious to undermine his theory. And that mistake has only recently been recognized as such. . . . At one point in his argument, Darwin was misled."

Although I will try to refute Bethell, I also deplore the unwillingness of scientists to explore seriously the logical structure of arguments. Much of what passes for evolutionary theory is as vacuous as Bethell claims. Many great theories are held together by chains of dubious metaphor and analogy. Bethell has correctly identified the hogwash surrounding evolutionary theory. But we differ in one fundamental way: for Bethell, Darwinian theory is rotten to the core; I find a pearl of great price at the center.

Natural selection is the central concept of Darwinian theory—the fittest survive and spread their favored traits through populations. Natural selection is defined by Spencer's phrase "survival of the fittest," but what

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does this famous bit of jargon really mean? Who are the fittest? And how is "fitness" defined? We often read that fitness involves no more than "differential reproductive success"—the production of relatively more successful offspring than other competing members of the population. Whoa! cries Bethell, as have many others before him. This formulation defines fitness in terms of survival only. The crucial phrase of natural selection means no more than "the survival of those who survive"—a vacuous tautology. (Tautologies are fine as definitions, but not as testable scientific statements—there can be nothing to test in a statement true by definition.)

But how could Darwin have made such a monumental, two-bit mistake? Even his severest critics have never accused him of crass stupidity. Obviously, Darwin must have tried to define fitness differently—to find a criterion for fitness independent of mere survival. Darwin did propose an independent criterion, but Bethell argues quite correctly that he relied upon analogy to establish it, a dangerous and slippery strategy. One might think that the first chapter of such a revolutionary book as *Origin of Species* would deal with cosmic questions and general concerns. It doesn't. It's about pigeons. Darwin devotes most of his first forty pages to "artificial selection" of favored traits by animal breeders. For here an independent criterion surely operates. The pigeon fancier knows what he wants. The fittest are not defined by their survival. They are, rather, allowed to survive because they possess desired traits.

The principle of natural selection depends upon the validity of this analogy with artificial selection. We must be able, like the pigeon fancier, to identify the fittest beforehand, not only by the a posteriori fact of their survival. But nature is not an animal breeder; no preordained purpose regulates the history of life. In nature, any traits possessed by survivors must be counted as "more evolved"; in artificial selection, "superior" traits are defined before breeding even begins. Later evolutionists, Bethell argues, recognized the failure of Darwin's analogy and redefined "fitness" as mere survival. But they did not realize that they had undermined the logical structure of Darwin's central postulate. Nature provides no independent criterion of fitness; thus, natural selection is tautological.

Bethel then moves to two important corollaries of his major argument. First, if fitness only means survival, then how can natural selection be a "creative" force, as Darwinians insist. Natural selection can only tell us how "a given type of animal became more numerous"; it cannot explain "how one type of animal gradually changed into another." Secondly, why were Darwin and other eminent Victorians so sure that mindless nature could be compared with conscious selection by breeders. Bethell argues that the cultural climate of triumphant industrial capitalism had defined any change as inherently progressive. Mere survival in nature could only be for the good: "It is beginning to look as though what Darwin really discovered was nothing more than the Victorian propensity to believe in progress."

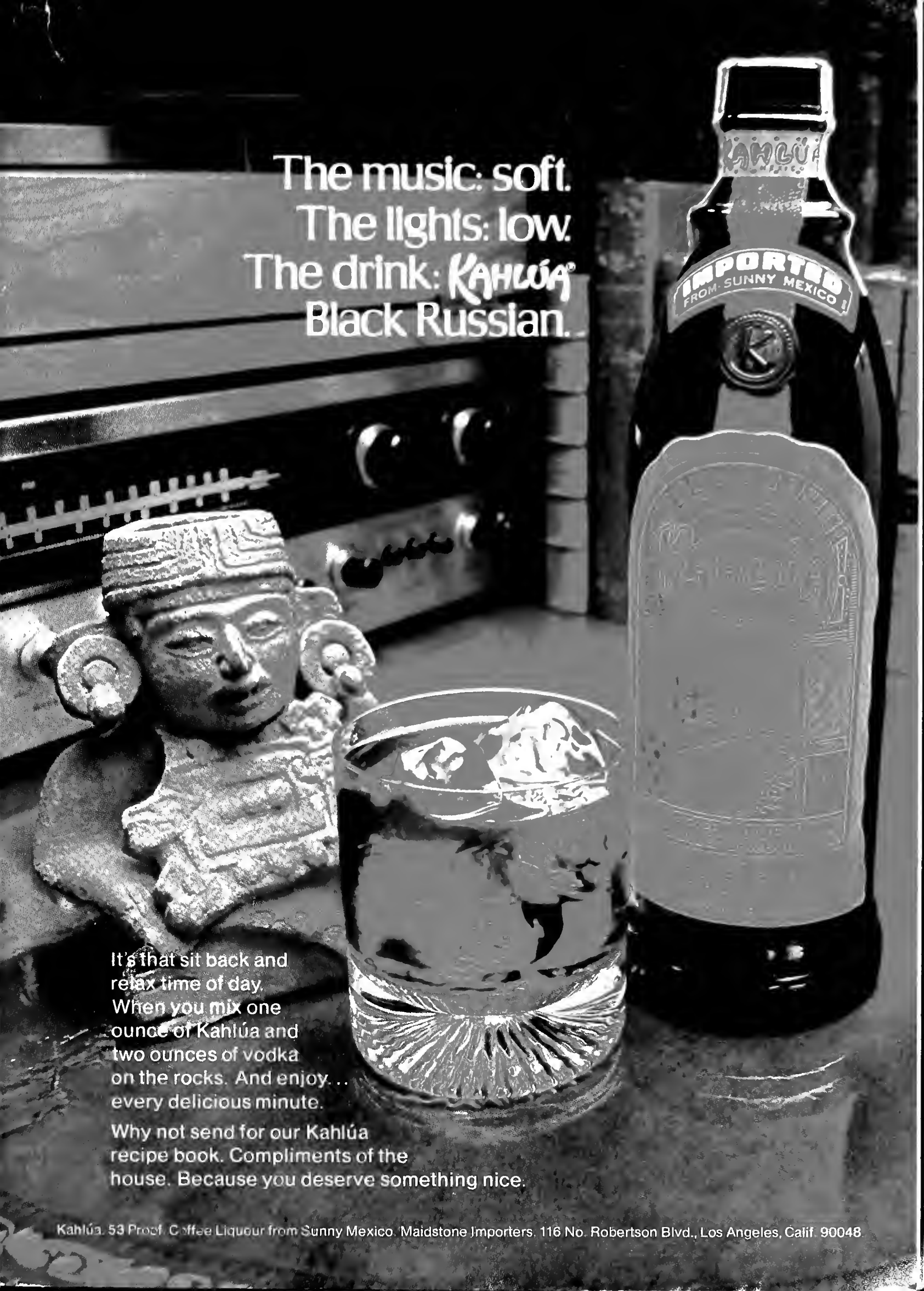
I believe that Darwin was right and that Bethell and his colleagues are wrong: criteria of fitness independent of survival can be applied to nature and have been used consistently by evolutionists. But let me admit that Bethell's criticism applies to much of the technical literature in evolutionary theory, especially to the abstract mathematical treatments that consider evolution only as an alteration in numbers, not as a change in quality. These studies do assess fitness only in terms of differential survival. What else can be done with abstract models that trace the relative successes of hypothetical genes A and B in populations that exist only on computer tape? Nature, however, is not limited by the calculations of theoretical geneticists. In nature, A's "superiority" over B will be expressed as differential survival, but it is not defined by it—or, at least, it better not be so defined, lest Bethell et al. triumph and Darwin surrender.

My defense of Darwin is neither startling, novel, nor profound. I merely assert that Darwin was justified in analogizing natural selection with animal breeding. In artificial selection, a breeder's desire represents a "change of environment" for a population. In this new environment, certain traits are superior a priori; (they survive and spread by our breeder's choice, but this is a result of their fitness, not a definition of it). In nature, Darwinian evolution is also a response to changing environments. Now, the key point: certain morphological, physiological, and behavioral traits should be superior a priori as designs for living in these new environments. These traits confer fitness by an engineer's criterion of good design, not by the empirical fact of their survival and spread. It got colder before the woolly mammoth evolved its shaggy coat.

Why does this issue agitate evolutionists so much? OK, Darwin was right: superior design in changed environments is an independent criterion of fitness. So what. Did anyone ever seriously propose that the poorly designed shall triumph? Yes, in fact, many did. In Darwin's day, many rival evolutionary theories asserted that the fittest (best designed) must perish. One popular notion—the theory of racial life cycles—was championed by a former inhabitant of the office I now occupy, the great American paleontologist Alpheus Hyatt. Hyatt claimed that evolutionary lineages, like individuals, had cycles of youth, maturity, old age, and death (extinction); that decline and extinction are programmed into the history of species; and that as maturity yields to old age, the best-designed individuals die and the hobbled, deformed creatures of phyletic senility take over. Another anti-Darwinian notion, the theory of orthogenesis, held that certain trends, once initiated, could not be halted, even though they must lead to extinction caused by increasingly inferior design. Many nineteenth-century evolutionists (perhaps a majority) held that Irish elks became extinct because they could not halt their evolutionary increase in antler size; thus, they died—caught in trees or bowed (literally) in the mire. Likewise, the demise of saber-toothed tigers was often attributed to canine teeth grown so long that the poor cats couldn't open their jaws wide enough to use them.

Thus, it is not true, as Bethell claims, that any traits possessed by survivors must be designated as fitter. "Survival of the fittest" is not a tautology. It is also not the only imaginable or reasonable reading of the evolutionary record. It is testable. It had rivals that failed under the weight of contrary evidence and changing attitudes about the nature of life. It has rivals that may succeed, at least in limiting its scope (see my column of December 1975, on the evolution of selectively neutral traits).

If I am right, how can Bethell claim, "Darwin, I suggest, is in the



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process of being discarded, but perhaps in deference to the venerable old gentleman, resting comfortably in Westminster Abbey next to Sir Isaac Newton, it is being done as discreetly and gently as possible with a minimum of publicity." I'm afraid I must say that Bethell has not been quite fair in his report of prevailing opinion. He cites the gadflies C.H. Waddington and H.J. Muller as though they epitomized a consensus. He never mentions the leading selectionists of our present generation—E.O. Wilson or D. Janzen, for example. And he quotes the architects of neo-Darwinism—Dobzhansky, Simpson, Mayr, and J. Huxley—only to ridicule their metaphors on the "creativity" of natural selection. (I am not claiming that Darwinism should be cherished because it is still popular; I am enough of a gadfly to believe that uncriticized consensus is a sure sign of impending trouble. I merely report that, for better or for worse, Darwinism is alive and thriving, despite Bethell's obituary.)

But why was natural selection compared to a composer by Dobzhansky; to a poet by Simpson; to a sculptor by Mayr; and to, of all people, Mr. Shakespeare by Julian Huxley? I won't defend the choice of metaphors, but I will uphold the intent, namely, to illustrate the essence of Darwinism—the creativity of natural selection. Natural selection has a place in all anti-Darwinian theories that I know. It is cast in a negative role as an executioner, a headsman for the unfit (while the fit arise by such non-Darwinian mechanisms as the inheritance of acquired characters or direct induction of favorable variation by the environment). The essence of Darwinism lies in its claim that natural selection creates the fit. Variation is ubiquitous and random in direction. It supplies the raw material only. Natural selection directs the course of evolutionary change. It preserves favorable variants and builds fitness gradually. In fact, since artists fashion their creations from the raw material of notes, words, and stone, the metaphors do not strike me as inappropriate. Since Bethell does not accept a criterion of fitness independent of mere survival, he can hardly grant a creative role to natural selection.

According to Bethell, Darwin's concept of natural selection as a creative force can be no more than an illusion encouraged by the social and

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political climate of his times. In the throes of Victorian optimism in imperial Britain, change seemed to be inherently progressive; why not equate survival in nature with increasing fitness in the nontautological sense of improved design.

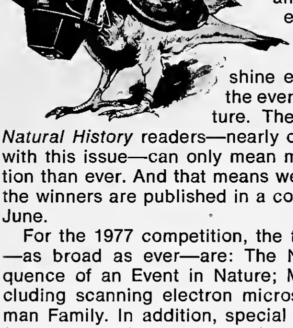
I am a strong advocate of the general argument that "truth" as preached by scientists often turns out to be no more than prejudice inspired by prevailing social and political beliefs. I have devoted several columns to this theme because I believe that it helps to "demystify" the practice of science by showing its similarity to all creative human activity. But the truth of a general argument does not validate any specific application, and I maintain that Bethell's application is badly misinformed.

Darwin did two very separate things: he convinced the scientific world that evolution had occurred and he proposed the theory of natural selection as its mechanism. I am quite willing to admit that the common equation of evolution with progress made Darwin's first claim more palatable to his contemporaries. But Darwin failed in his second quest during his own lifetime. The theory of natural selection did not triumph until the 1930s. Its Victorian unpopularity lay, in my view, primarily in its denial of general progress as inherent in the workings of evolution. Natural selection is a theory of local adaptation to changing environments. It proposes no perfecting principles, no guarantee of general improvement; in short, no reason for general approbation in a political climate favoring innate progress in nature.

Darwin's independent criterion of fitness is, indeed, "improved design," but not "improved" in the cosmic sense that contemporary Britain favored. To Darwin, improved meant only "better designed for an immediate, local environment." Local environments change constantly: they get colder or hotter, wetter or drier, more grassy or more forested. Evolution by natural selection is no more than a tracking of these changing environments by differential preservation of organisms better designed to live in them: hair on a mammoth is not progressive in any cosmic sense. Natural selection can produce a trend that tempts us to think of more general progress—increase in brain size does characterize the evolution of group after group of mammals (see my column of January 1975). But big brains have their uses in local environments; they do not mark intrinsic trends to higher states. And Darwin delighted in showing that local adaptation often produced "degeneration" in design—anatomical simplification in parasites, for example.

If natural selection is not a doctrine of progress, then its popularity cannot reflect the politics that Bethell invokes. If the theory of natural selection contains an independent criterion of fitness, then it is not tautological. I maintain, perhaps naïvely, that its current, unabated popularity must have something to do with its success in explaining the admittedly imperfect information we now possess about evolution. I rather suspect that we'll have Charles Darwin to kick around for some time.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.



The 1977 *Natural History* Photographic Competition

All signs indicate a glorious photographic competition is in the offing for 1977. Film sales and photographic processing reached all-time peaks this summer. The sun seemed to shine especially bright upon the ever beautiful world of nature. The growing number of *Natural History* readers—nearly one and a half million with this issue—can only mean more intense competition than ever. And that means we will all benefit when the winners are published in a color-packed issue next June.

For the 1977 competition, the four major categories —as broad as ever—are: The Natural World; A Sequence of an Event in Nature; Microphotography, including scanning electron microscopes; and The Human Family. In addition, special awards will be made for the single best pictures showing humor and urban wildlife.

The rules are simple: (1) The competition is open to everyone, except employees of The American Museum of Natural History and their kin; (2) Competitors may submit up to three previously unpublished entries in each of the four categories; (3) Entries may be transparencies or prints up to 8 by 10 inches, and *each* must contain the name and address of the photographer, because keeping track of the thousands of entries is a big job; (4) For each entry, we would like to know the camera model used; and (5) Include a self-addressed stamped envelope—we do want to return your pictures to you.

The contest opens January 1 (which still gives you time to shoot a winner) and closes March 1.

Now for the important detail—the rewards to winners. In addition to being published in the magazine, First Prize winners in the four major categories will each receive $400. The special humor and urban wildlife winners will each get $200. Ten Honorable Mentions will receive $100 each.

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Cardinal

Meadowlark

How the Wise Men Brought Malaria to Africa

by Robert S. Desowitz

And other cautionary tales of human dreams and opportunistic mosquitoes

Once upon a time (but not too long ago) there lived a tribe deep within the Dark Continent. These people tilled the soil to raise crops of roots and grains, for they had little meat to lend them strength. Illness often befell them, but even so, in this dry land they were not overly troubled with the fever sickness brought by the mosquito. Now in the Northern World there was a powerful republic that had compassion on these people and sent their Wise Men to relieve the mean burden of their lives. The Wise Men said, "Let them farm fish," and taught the people to make ponds and to husband a fish called tilapia.

The people learned well, and within a short time they had dug 10,000 pits and ponds. The fish flourished, but soon the people could not provide the constant labors required to feed the fish and keep the ponds free of weeds. The fish became smaller and fewer, and into these ponds and pits came the fever mosquitoes, which bred and multiplied prodigiously. The people then sickened and the children died from the fever that the medicine men from the cities called malaria. The Wise Men from the North departed, thinking how unfortunate it was that these people could not profit from their teachings. The people of the village thought it strange that Wise Men should be sent them to instruct in the ways of growing mosquitoes.

At about the same time, from 1957 to 1961, that this ecological misadventure was taking place in Kenya (for it was no fable), on the other side of the world the impoverished villagers of the Demerara River estuary in Guyana were enacting their own calamity. Striving to improve their lot by converting from subsistence farming of maize and cassava to cash-producing rice, they cleared the region for rice fields, displacing the livestock that formerly abounded in the villages. Mechanization on the roads and fields also progressed, bringing a further diminution in the numbers of domestic animals, particularly of cattle and draft oxen.

The major potential carrier of malaria in the region was the mosquito *Anopheles aquasalis*, but since subsistence agriculture created few suitable water collections for breeding, the mosquitoes were present in only modest density. The wet rice fields, however, provided an ideal larval habitat and the vector population increased rapidly. Even so, all would have been well had there been no alteration in the livestock since the genetically programmed behavior of *A. aquasalis* directs them to prefer blood meals from domestic animals rather than humans. With the disappearance of their normal food supply, however, the hungry mosquitoes turned their attention to people. Intense mosquito–man contact now enhanced malaria transmission to epidemic proportions. And so the combination of rice and tractors contrived to bring malaria to the people of the Demerara River estuary.

These two stories of ecological disaster are not isolated phenomena. In the endemic regions of the tropics, many human activities create and multiply the breeding habitats of malaria-bearing mosquitoes. Thus, in their very attempts to break from the bondage of poverty, food shortage, and ill health, third world peoples too

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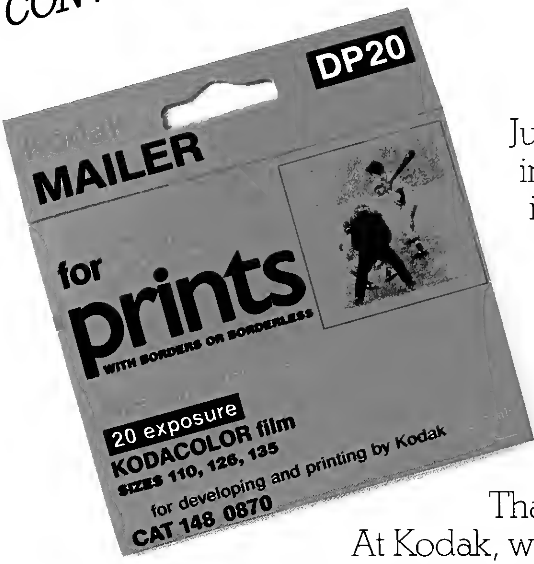

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often sow the seeds of disaster in the form of malaria.

Malaria of humans is caused by four species of a protozoan parasite of the genus *Plasmodium*—*P. falciparum*, *P. vivax*, *P. malariae*, and *P. ovale*. While all four species of parasites can produce debilitating illness, only *P. falciparum* is sufficiently virulent to cause death. The complicated life cycle is, in the main, the same for all species. Two hosts are required: man and a mosquito of the genus *Anopheles*. Infection in man begins with the bite of the mosquito, which injects sporozoites, microscopic threadlike forms, into the human host. The sporozoites enter liver tissue, where they divide asexually to form daughter cells. A single sporozoite may give rise to as many as 30,000 daughter cells. After a sojourn in the liver that may last from several weeks to months or even years, depending on the species and strain of parasite, the cells are released from the liver and enter the circulation, where they invade red blood cells.

Within the red blood cells the parasite grows, the nucleus divides, and in a manner analogous to the liver phase, ten to sixteen daughter cells are produced. The red cell finally bursts, freeing the daughter cells to invade new red blood cells. Since the cycle is synchronous, it causes periodically recurrent episodes of chills and fever—hallmarks of malaria infections.

Several days after the onset of the blood phase, new forms appear within the red blood cells. These sexual stages, the male and female gametocytes, undergo no further change until ingested by the feeding mosquito. A marvelously adaptive process has evolved in which the gametocytes are mature and infective to the mosquito for only a short period of the day. This period of infectivity occurs at night, matching the time that most anopheline carriers take their blood meal.

In the mosquito stomach the gametocytes are transformed into male and female gametes and fertilization occurs. The fertilized female gamete penetrates the mosquito stomach wall, coming to rest on the exterior surface where it forms a cystlike body, the oocyst. Within this cyst intense cytoplasmic reorganization and nuclear division take place, and as many as 10,000 sporozoites form. The formation of the oocyst takes seven to fourteen days, depending on temperature and other factors. Upon maturation it bursts, releasing the sporozoites, which invade the salivary glands. The mosquito can now infect a human when next it feeds.

The anopheline mosquito is the critical link in perpetuating the malaria parasite, and the nature of man–mosquito contact greatly influences the level of endemism. An important factor in this relationship is the life cycle of the mosquito in interaction with its environment. Each anopheline species has characteristic biological and behavioral traits that determine its interaction with man and other hosts. Thus, the selection for breeding water, host upon which to feed, and resting behavior are genetically controlled characteristics, which may or may not place a particular anopheline mosquito in proximity to man. In many regions of the tropics, human activities, particularly those associated with agriculture, alter the environment, producing suitable breeding sites and increasing the likelihood of human contact with malarial mosquitoes.

Of all the agricultural practices that alter the natural tropical ecosystem, rice culture is one of the most important in creating optimal conditions for malaria transmission. Rice farming requires large, open areas of water, also the preferred habitat of many of the most efficient anopheline carriers of malaria. These conditions are especially evident in new rice fields, where the young plants are placed well apart. Also, the generation time of the mosquito is accelerated in the sun-elevated temperature of the exposed water, and breeding is prolific. In addition, a relatively large body of standing water increases the humidity of the surrounding biosphere, and the higher humidity prolongs the mosquito's life. The longer a mosquito lives, the more people it bites during its lifetime.

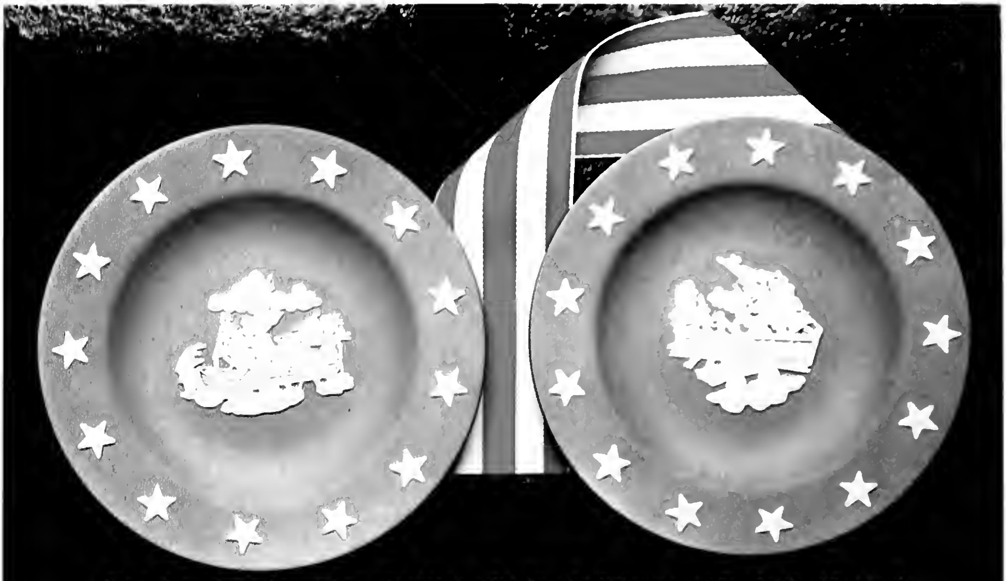
A vicious series of events may develop beginning with the intense man–vector contact. Because rice culture is seasonal, peak densities of mosquitoes generally occur for relatively short periods. The limited transmission period prevents the development of a protective immunity. When farmers are incapacitated by malaria during the planting season, crop production suffers, leading to economic loss and food shortage.

The ecological changes described above have been excellently documented in a study carried out on Kenya's Kano Plain rice development scheme. Prior to establishment of the rice plots, the Kano Plain landscape was characterized by villages of scattered huts, maize farms interspersed with seasonal swamps and water holes in which *Pistia* plants grew. In this unmodified environment, 99 percent of the mosquito population were *Mansonia*, a nonvector of malaria, while only 1 percent were *Anopheles gambiae*. After the land was modified for rice farming, 65 percent of the mosquitoes were *A. gambiae* and 28 percent *Mansonia* (the other 7 percent were another variety). Similar alterations in mosquito populations following the introduction of rice farming have occurred in such diverse areas of the world as Venezuela, Tanzania, India, Syria, and Morocco, where until 1949 the French colonial government had, for health reasons, banned rice growing.

In the tropical world the ecosystem undergoing the most rapid and extensive alteration for human purposes is the forest. These alterations have frequently resulted in an intensification of malaria, often out of all proportion to the small degree of disturbance created.

Within the intact tropical rain forest there are relatively few species of mosquitoes that transmit human malaria. Not only are there few permanent or semipermanent water collections but also the main anopheline carriers prefer sunlit breeding sites and avoid shaded conditions. But breeding conditions abound in the exposed water collections created when the forest is cleared by the farmer digging his plot of ground, by tractors and other machines used for lumbering, and by the rutted roads used to service the new settlements.

Conversely, on at least one occasion, the creation of forests has also led to problems. When the cacao industry was begun in Trinidad, a manmade forest of immortelle trees was planted to provide the shade required by cacao plants. Certain South and Central American anophelines, showing the remarkable specialization a mosquito species may have, breed exclusively in water contained in the bromeliad epiphytes of the forest gallery. When bromeliads colonized the high immortelle trees, *A. bellator* proliferated, carrying malaria to the plantation workers and their families.



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In an attempt to solve their problems—overcrowded cities, land shortage, and the need for establishing a market economy—political and technical authorities in the developing countries have opened new lands to agricultural development. Such projects commonly begin with the clearing of the jungle, followed by resettlement of transmigrants and cultivation of cash crops such as cotton, tobacco, rice, and corn. But all too frequently, the ecological alterations brought about by deforestation, creation of irrigation systems, and other human activities enhance the vector population. More often than not, settlers brought into the area have had little exposure to malaria and have not acquired sufficient immunity to protect them from severe attacks. For example, within eight months of leaving nonmalarious urban centers of Java for an agricultural project in south Sulawesi, 32 percent of the settlers were stricken with malaria and the enterprise nearly collapsed.

The ability to protect the settlers by chemical control of the anopheline carrier has often been negated by prior use of agricultural insecticides such as DDT. Spraying crops to protect against the ravages of destructive insects and spraying for the control of anopheline vectors involve different and generally incompatible techniques. Where insecticide has been broadcast for crop protection, the anopheline population contracts sublethal doses that eventually render it physiologically or behaviorally resistant. Thus, by the time antimalaria measures are instituted, the avenue of mosquito control by chemical means has been closed.

Cost accounting of the economics of ecological alteration is difficult, particularly when the influence of a single factor, malaria, is traced through a complicated, interacting mosaic. One excellent exercise in ecological–economic sleuthing was carried out by the Pan American Health Organization after new lands had been opened for agricultural development in Paraguay. In the first year of the scheme, malaria seriously afflicted the settlers and the impact of the disease reduced the over-all production of cash crops—tobacco, cotton, and corn—by 36 percent. Worker efficiency, particularly during the harvest, which coincided with the height of the malaria season, was reduced by as much as 33 percent. Debilitated by malaria, the farmers devoted their limited energy to their cash crops, abandoning for subsistence all but the easily cultivated, but starchy, manioc. As a result, deterioration of their nutritional status was added to the burden of malaria.

In subsequent years there was reduced expansion of farms in the malaria-struck region. Tragically, the Paraguayan government and its advisers were aware of the health hazards, but having expended a large amount of capital on land development, it had too little left in the kitty to secure its "beachhead" by providing the infrastructure of health, education, and other social services. The Paraguayan experience has been repeated throughout the tropics.

In addition to agricultural development, third world governments have expanded electrical power resources in their attempts to promote economic development. But along with the kilowatts, rice, and fish, these giant hydroelectric and water impoundment schemes also produced malaria. The seepages and canals have provided optimal breeding habitats for malaria mosquitoes in such geographically diverse projects as the Aswan Dam in Egypt, the Kariba project in Zambia, the Lower Seyhan

project in Turkey, and early in its history, the TVA scheme in the United States. On occasion, the dams and man-made lakes were not in themselves responsible for ecological change leading to intensified malaria transmission but, rather, set in motion a train of events that led to the situation. Construction of the Kalimawe Dam in Tanzania, for example, extended cultivation far beyond the original plots. This made it necessary to graze cattle, the preferred host of the local *A. gambiae*, farther from the villages. When the cows were no longer kept near houses at night, the peridomestic mosquitoes were diverted to man, and malaria transmission was intensified.

Ecological alterations have been caused not only by man's struggles toward progress but also by his conflicts; throughout the course of history the environment has been a casualty of war. This ecological havoc has often created conditions conducive to malaria transmission in both temperate and tropical regions, and epidemics of malignant malaria have victimized military personnel and civilians.

During World War II, for example, the bloody fighting near Cassino, Italy, destroyed dikes containing the rivers. Anopheline mosquitoes bred profusely in the flooded areas and bomb craters. Malaria, possibly introduced by foreign troops, occurred in its most violent form, with some villages totally infected and suffering a mortality rate of 10 percent. But it was in the Vietnam conflict that a new and devastating tactical strategy was applied—the ecosystem became a deliberate target of massive destruction. The use of aircraft-spread herbicides for the defoliation of forests and destruction of crops introduced a new dimension to the horror of war. Scientists throughout the world were alarmed, and a number of studies were conducted to determine the consequences of defoliation.

One such study, that of the congressionally funded National Academy of Sciences committee, included an investigation of epidemiological–ecological interactions in the defoliated mangrove forest south of Saigon, a region known as the Rung Sat. This area, repeatedly sprayed with herbicide, had become a desolate, barren wasteland denuded of virtually every living tree. Studying an intact mangrove forest as a control, the NAS medical ecologists did not detect any breeding sites of anopheline mosquitoes. Other mosquitoes were abundant but the Southeast Asian mangrove ecosystem was not the kind of real estate suitable for anophelines. In the Rung Sat, however, the mosquito population consisted largely of *A. sinensis* and *A. lesteri*. Malaria was endemic throughout the region.

Again, rice seems to have been the final ecological culprit. As people were deprived of their main livelihood from woodcutting, they turned to rice culture in the less saline areas of the dead mangrove. The rice fields provided ideal breeding sites for the two anopheline species.

In Vietnam the main foci of malaria are found in the montane forests, the vectors being *A. maculatus*, breeding in exposed hillside streams, and *A. balabacensis*, living in sunlit standing collections of water. Removal of the forest's shade cover created new breeding sites for these mosquitoes. At the time of the NAS study in Vietnam the temperature of the war was too hot to permit on the ground study, but when the study group flew over the deforested mountain areas, they saw a landscape typically colonized by these two efficient vectors. Notably, American soldiers fighting in the Vietnam highland forests were severely afflicted by malaria, with the attack rate in some units as high as 53 cases per 1,000 troops per day.

Paradoxically and cruelly, in the absence of an effective control program, a community's welfare and stability often depend on continuous, intense exposure to malaria. Under these conditions, as in the agricultural villages of Africa and Southeast Asia, malaria accounts for high infant mortality; some 40 percent or more of the children under the age of five may die of the infection. Those who survive, however, develop a protective immunity, and adults, the productive segment of the community, remain relatively free of the pernicious clinical manifestations of the infection. Usually, the high infant mortality is compensated by a high birthrate, and so a population equilibrium is achieved in which the workers are sufficiently healthy to provide the community's food requirements.

The relatively slow acquisition of functional immunity to malaria and its concomitant cost in infant life have led to several disasters of good intent and have presented new moral dilemmas for discomfited public health workers. The Western and Western-trained health professionals have held, by tradition and education, the philosophy of the importance of individual human life and the right of every member of the community to good health. The heroic efforts begun in the mid-1950s to realize global eradication of malaria were rooted in this moral premise. But where these control programs were successful in the developing tropical countries, population numbers increased rapidly, while technical-agricultural resources to accommodate the burgeoning community lagged sadly behind. Following a successful control scheme in Guyana, infant mortality was reduced to one-third its former rate; in one study group, a sugar plantation village, the population rose from the precontrol level of 66,000 in 1957 to 110,000 in 1966. Some students of public health, as well as health officials, are now beginning to question the wisdom of instituting such measures as malaria control unless they are accompanied by effective population control programs or by expansion of resources to feed, clothe, educate, and house the increased population.

The disasters of good intent are related to malaria's tendency to return several years after a successful mosquito control program. During this period the mosquito populations have once again returned to former density, and the human population's collective immunity has waned. Wherever it recurs under these circumstances, malaria is explosive and clinically severe.

It is doubtful whether progress for the peoples of the developing world, as we define progress, can be achieved unless malaria and other diseases draining their intellectual and physical energies can be brought under control. Yet the enterprises of progress contribute, with monotonous regularity, to the deterioration of health. What is now required is a holistic approach. Engineers, agronomists, epidemiologists, economists, ecologists, demographers, cultural anthropologists, and political leaders must all contribute to the planning, execution, and evaluation processes. In this way, malaria and many other diseases can be reduced to a manageable state if not actually eradicated. Human needs demand it; human intelligence and ingenuity must be turned to achieving a degree of progress, rather than disaster, for the peoples of the third world. □

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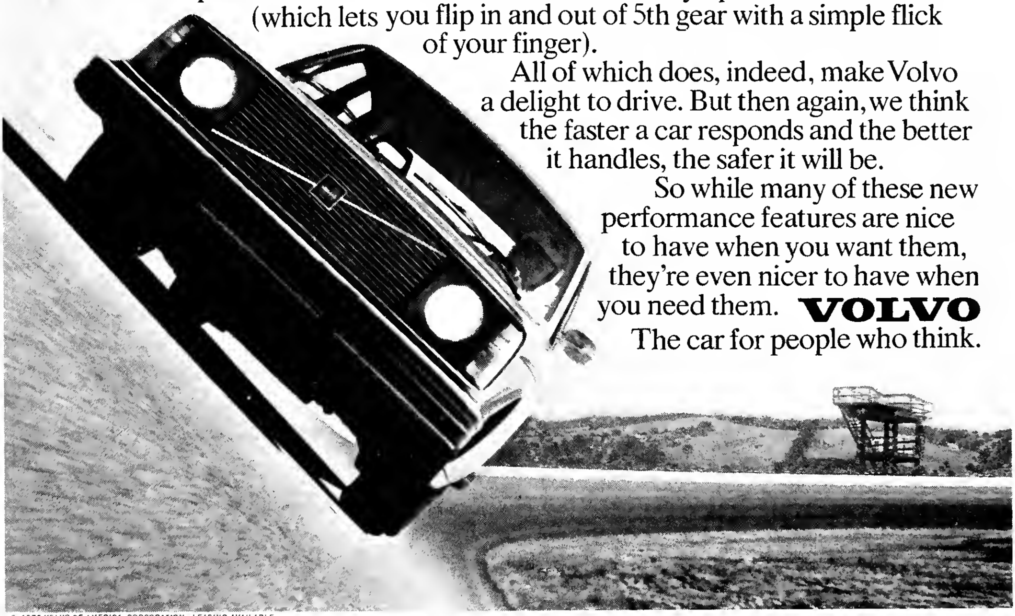

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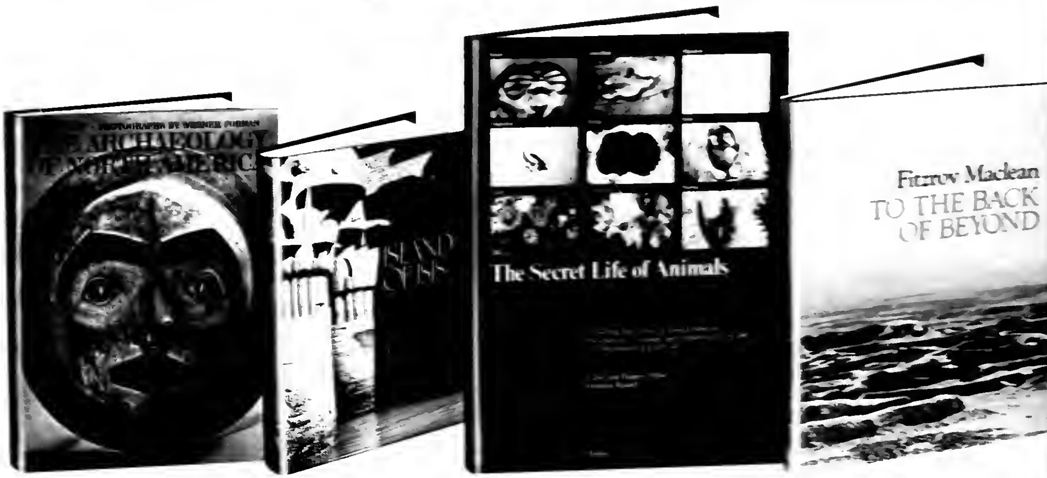

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Bermuda's Abundant, Beleaguered Birds

by Kenneth L. and Marnie Reed Crowell

Native creatures have suffered as man has used and tried to improve this island paradise

To the casual visitor, Bermuda retained its virgin charm as late as 1945. At that time, the native songbirds were still abundant and the island cluster was clothed in the deep green of Bermuda cedars. Now, the native birds are drastically diminished and the cedars have all but disappeared. Despite further changes in Bermuda's environment as a result of a tremendous increase in the human population, it remains a vacationer's paradise because of its lush subtropical vegetation and climate.

Although Bermuda lies in the North Atlantic, 580 miles east of North Carolina, it is bathed by the warm waters of the Gulf Stream, making it the world's most northerly coral reef. Bermuda is only twenty square miles in area, and like most oceanic islands it has an impoverished fauna and flora, with several unique or endemic forms.

Through its meager fauna, Bermuda provides insights into the dynamics of more complex mainland communities. Ecological relationships that might be overlooked in continental ecosystems quickly become apparent in an island microcosm. Islands, particularly, reveal the effects of introduced species. As landscapes are increasingly altered by modern technology, the influence of these alien, or exotic, species multiplies. Suburbanization favors those plants and animals that can take advantage of disturbed habitats. On Bermuda, as elsewhere, this is occurring at the expense of native species.

Because of its proximity to the Gulf Stream, Bermuda's plants were largely of West Indian origin: palmetto and Bermuda cedar and several unusual hardwoods in the uplands; saw grass and sword fern in the wooded swamps or open savannas of the lowlands. Mangrove thickets fringed the coastal areas and brackish ponds. Bermuda has no native amphibians and only one reptile—an endemic skink, which still survives. There were no native mammals and only a few species of birds.

Even before the island was settled, the natural communities had been greatly altered. Henry May, an Englishman shipwrecked on Bermuda in 1593, found it overrun with feral hogs, descendants of animals liberated by Spaniards decades before to provide a food source for the crews of their ships in these distant waters. The hogs destroyed much of the vegetation and reduced the numbers of ground-nesting birds—particularly the Bermuda petrel, or cahow.

May and the other survivors of the wreck of the *Bonaventura* chopped down many of the ubiquitous Bermuda cedars to build a ship in which they were able to continue their voyage. Permanent settlers soon arrived and busily set about changing the landscape of this strategic outpost of the New World. With them came rats from ships and, in due time, cats to eat the rats—and the island birds, which previously had had few predators. At this time one or more species of endemic finches may have been extirpated. Although many shorebirds visited the islands during migration, only a few, such as the coot, purple gallinule, and several species of herons, bred in Bermuda. Among the nesting seabirds were the cahow, the white-tailed tropicbird, and Audubon's shearwater. There were hawks, probably including the kestrel and osprey, and there certainly were crows. The only other native passerine birds to sing to those hardy early settlers were the catbird, eastern bluebird, and Bermuda white-eyed vireo—an endemic subspecies.

In the years that followed, colonists brought birds from their native lands to the little island: the ground dove was probably introduced in the seventeenth century; the cardinal in the eighteenth century. In the nineteenth century, settlers brought the bobwhite, the European goldfinch, and the house sparrow. In the twentieth century, the ring-necked pheasant and the mockingbird enjoyed limited success and Portuguese immigrants brought the wild canary from the Azores. The hawks were gone, but with the increase in rats and mice, the cosmopolitan barn owl was able to colonize in the 1930s. However, this pest-control agent is now threatened by commercial rat poison contained in the rodents on which it feeds. In early attempts at natural insect control, *Bufo marinus* toads were brought from British Guiana, as well as two kinds of "whistling" frog and one species of *Anolis* lizard from the West Indies.

Throughout the centuries Bermudians, in efforts to improve on nature, have introduced more than 1,500 species of plants, of which about 800

Introduced about 200 years ago, the cardinal (female, right) is firmly established in Bermuda. It nests and feeds in the ornamental bushes planted by homeowners.

Kirtley-Perkins; Photo Researchers


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Common terns, above, nest on the Bermuda coast. Their reproductive success can be affected by insecticides. The purple gallinule, left, is only a migrant species.

have become naturalized. Such introduced plants as jasmine vine and fennel escaped from garden plots and took over the new land with the vengeance of weeds. The native palmetto, originally intermingled with the cedar, fell to the ax, as did the yellowwood and endemic olivewood trees, valuable for their fine-grained wood. Bermuda cedar was heavily cut for its beautiful and fragrant wood and suffered competition from such aggressive newcomers as fiddlewood and allspice. In the early decades of the seventeenth century, however, a decree proscribing further cutting of the cedar became the first forestry law of the New World, while Bermuda laws protecting the green turtle and cahow were the first wildlife protection measures.

Ecological disaster concealed in a shipment of nursery plants struck the island about 1946. In just three years, nearly half the Bermuda cedars were dead or dying. By 1951, 85 percent had been wiped out. The culprit, a scale insect, was a notorious pest of ornamental and citrus plants.

Government officials rapidly implemented control measures by introducing predatory ladybird beetles and parasitic Hymenoptera, but they failed to thrive. A visiting biological-control expert hypothesized that they were falling prey to the numerous small *Anolis* lizards, which were only doing the job for which they had been brought to Bermuda in the first place. Immature ladybird beetles were also being consumed by two introduced ant species. Although the ants were in turn eaten by the lizards, officials recommended introduction of the kiskadee, a large West Indian flycatcher, to control the lizards. In 1956/1957, despite the protests of local conservationists, some 200 kiskadees were released in the vain hope that they would eat the lizards that ate the ladybugs that

could not control the scale that killed the cedars.

Just after these events, we arrived to study the birds in Bermuda. Starlings, apparently strays from North America, first bred on the island in 1954. They numbered fewer than 200 as late as 1957 and might have been eradicated. But for once man chose not to meddle, and by 1970 the starling numbered a messy 50,000.

In 1959 the introduced bobwhite, wild canary, and rock dove, and the recently naturalized mourning dove and starling were all restricted in numbers and localized in distribution, and the kiskadee was just getting a foothold. Thus, although some 150 species visit the island regularly during migration, we found only eight common resident bird species—catbird, white-eyed vireo, crow, bluebird, cardinal, ground dove, European goldfinch, and house sparrow—most of which are also found in brushy fields and scrubby woodlands of eastern North America. Compared with similar habitats of the eastern seaboard, where we found twenty to thirty species, the Bermuda

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A Bermuda native, the eastern bluebird, above left, has declined due to competition from introduced house sparrows, destruction of the native cedar trees in which it nested, and the use of pesticides. The kiskadee, far left, was brought to Bermuda in the 1950s to control the introduced Anolis *lizards, which were eating the ladybird beetles imported to feed on the exotic scale insects that were killing the cedars. The kiskadee population is now rapidly increasing. Another native, the catbird, above, perching on an exotic fiddlewood tree that competes with the cedars, is dwindling in numbers. White-tailed tropicbirds, left, are surviving in a fairly large population.*

Adelfio Bertol

communities were still quite simple.

How does the total density of Bermuda birds compare with that of the more complex continental communities? To answer this question, we censused birds in several representative Bermuda habitats by counting singing males as they advertised their territories. Most of our common songbirds are monogamous, and the males defend the individual territories by means of vocal and visible displays. The number of pairs breeding in the area gives a conservative estimate of the population size.

We found that most of the eight resident species inhabited each of our census plots. There are three reasons for this. First, there is too little area of unusual habitat type, such as mangrove swamp, to support specialized species, and released from competition, those generalized species that are present occupy niches broader than they could have on the mainland. Second, there is little contrast between the various Bermuda habitats compared with the differences between those on the mainland. Third, topographic and soil-related features, as well as human disturbance of the land, make the habitats extremely patchy. Bermuda species have adapted to these transition areas.

Within each habitat the birds are less demanding in their choice of territory sites than on the mainland. The common species use the entire area, rather than occupying only select sites, and their territories form a highly packed mosaic. Many of the species on Bermuda thus attain greater densities than in any North American habitat. We found thirty to fifty pairs per ten acres, compared with twenty to thirty pairs in similar mainland habitats. There are fewer species, but in the absence of competitors they often become extraordinarily common, a characteristic typical of islands.

High population densities may be encouraged by the island's benign environment, which requires less energy for temperature maintenance or predator defense. More time and energy are allocated to increased intraspecific competition associated with high population levels and reproduction is curtailed. We found

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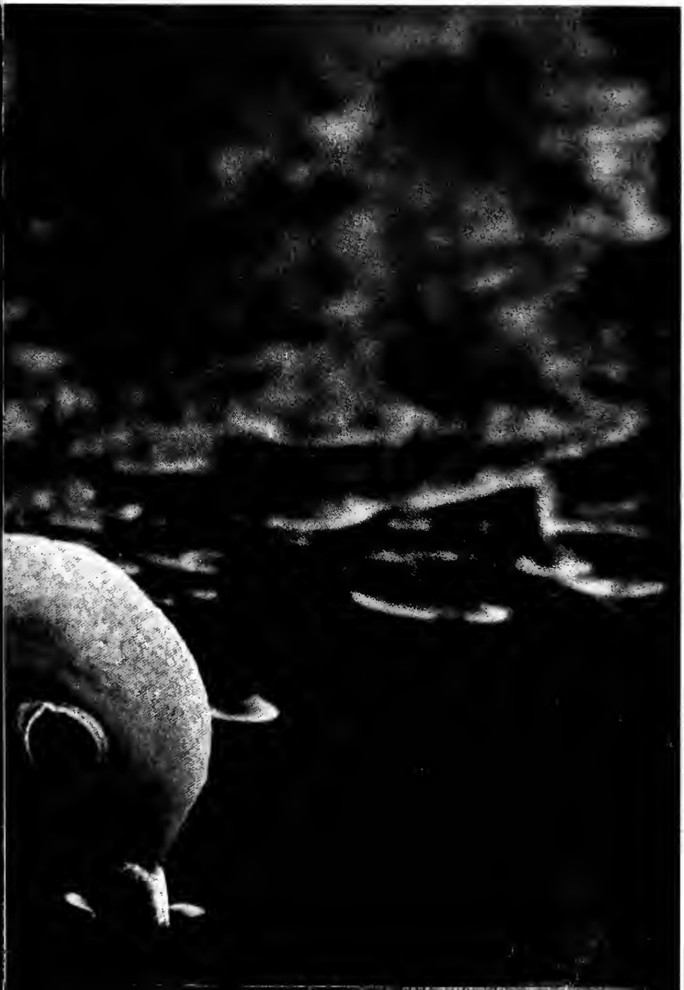


Construction of a beach club, above, has eliminated some bird habitat. The mourning dove, left, a recent immigrant, has benefited from the cutting of trees.

that average clutch size for both Bermuda catbirds and cardinals was lower than in coastal North America.

The favorable environment apparently also allows birds to live longer. Of nine adult white-eyed vireos banded in 1960, five were holding the same territories in 1964.

Age structure of the populations also differed from those on the mainland. David Wingate, Bermuda's chief conservation officer, found that 21 percent of 117 crows shot at roost were first-year birds, whereas more than half the crows shot at roost on the North American mainland consist of young of the year. Such reduced turnover of individuals results in a greater population.

One reason for the success of bird species on Bermuda is that they are able to take advantage of food or habitat normally utilized by missing competitors. This seems to be accomplished by increasing the frequency of certain feeding methods. The white-eyed vireo, for example, takes insects on the wing more frequently on Bermuda. This hawking behavior is more common to warblers on the mainland, being only occasionally observed in mainland vireos. Simi-

Joseph Van Wormer, Bruce Coleman, Inc

larly, catbirds in Bermuda spend more time feeding on the ground, a niche component shared with the towhee in North America.

On the mainland there are relatively few common species and many rare ones. On islands, rare species are fewer. Rare species may contribute to community stability. Coevolution of competitive and predator–prey interactions among the species of an ecosystem leads to a system of checks and balances. The more species, the more complex and sensitive is this equilibrium. An insular community with its few excessively common species is vulnerable to catastrophes. This is in part why the cedar scale was so devastating, why introduced rats, ants, and birds have all periodically reached pest proportions on Bermuda, and why one third of all extinctions in historic times have occurred on islands.

For three centuries Bermuda birds have been affected by changing patterns of land use. Today, open habitats, resulting from the cedar scale devastation and the clearing of land for new housing, have tipped the balance against Bermuda's native bird species. Our 1960 censuses provide a base line against which to measure some of these changes.

When we first visited our study areas, the burry song of the bluebird was common in the quiet lanes. The bluebird and the European goldfinch increased during the eighteenth and nineteenth centuries when woodlands were turned into fields. Indeed, so abundant were the bluebirds that they built nests in the open, as well as in natural cavities. With the arrival of the horse-and-buggy days at the turn of the century, the bluebird began to find itself pressed by competition. The house sparrow, able to scavenge grain from horse droppings as well as food from dumps and hotel patios, increased its numbers and competed with bluebirds for nest sites. Bluebirds suffered a further setback after the scale destroyed the cedars. Some 200,000 of the trees, in which the birds had commonly nested, were removed. At the same time, use of agricultural pesticides may have inhibited reproduction of this valuable insect eater.

Because no accurate censuses predate the cedar blight, we cannot be sure of its impact on the birds. The cedar provided rich cover both for feeding and nesting, so the bird populations must surely have suffered, at least initially. The bobwhite, which fed extensively on cedar berries, disappeared about 1960.

According to our censuses, 1970 was the first year in which native birds were outnumbered by the opportunistic house sparrow, kiskadee, and starling. Only the catbird remained more abundant than any of the new arrivals. The soft cooing of mourning doves now echoes in the lanes. Like the starling, they colonized naturally and only became widespread when they could take advantage of the open habitats created by the cedar blight. In 1960 they were not present in any of our census plots, but by 1970 they were abundant throughout the island, an increase that has been paralleled in suburban and rural areas of the United States. Similarly, populations of the rock dove, or common pigeon, small and localized for a century, are now reaching pest proportions.

Crows, too, have begun to figure more prominently in our censuses as they take advantage of the increase in man's garbage, waste dairy grain, and road kills. During the last ten years the population of 150 birds has increased to approximately 500, and the agricultural department has been forced to undertake control measures.

The omnivorous kiskadee has increased to an estimated 60,000 since its ill-advised introduction in the mid-1950s, and its raucous cries make it seem even more common. The Bermuda white-eyed vireo seems to have suffered not only from the loss of the cedars but also from direct depredation on its nestlings by the kiskadee. By 1970, the vireo, Bermuda's only endemic land bird, had declined 85 percent from 1960 levels, although in secondary forests its numbers are increasing somewhat.

More serious than the past changes in habitat is the current reduction in the quality and quantity of open space. In 1974 we found two of our study plots had been swallowed up by housing developments. The pace of traffic on the winding lanes had stepped up and exhaust fumes hung in the air. Lot size in housing subdivisions was decreasing. Bulldozers scraped building sites bare for replanting with neatly groomed lawns and a few ornamentals. The advent of the power mower reinforced what amounted to a conspiracy against Bermuda's vegetation. Noisy flocks of starlings were everywhere. In censuses of suburban areas of Bermuda we found that starlings and house sparrows account for more than half the birds, hardly surprising since they even utilize man's buildings for their nest sites.

In these suburban areas we found the cardinal, goldfinch, and kiskadee about as abundant as in our wild plots. Although nest boxes have aided the bluebird, the species is still decreasing in number. But the native catbird, a denizen of thickets, and the vireo, Bermuda's only foliage gleaner, have suffered with the disappearance of undergrowth. The latter species is threatened with extinction on the island.

The native birds of Bermuda are thus increasingly restricted to localized habitats. Maintenance of such environments is perhaps the key to survival for most of these species. Some of these isolated habitats are now being upgraded and preserved in the form of sanctuaries, largely due to the efforts of David Wingate. In these areas, he is replacing the associations of alien plants and animals with thousands of resistant cedars, native bay grapes, palmettos, and hardwoods. Today, on Nonsuch Island, one can walk once again under the canopy of a forest of native species—a living museum of Bermuda's past vegetation.

Such habitat sanctuaries could become more common. Municipal parks, suburban backyards, and even industrial parks could all become sanctuaries if proper planting were undertaken.

As microcosms, islands show the consequences of ecological abuses that we may at first overlook in more complex mainland communities. Opportunistic species everywhere take advantage of the disturbed habitats resulting from suburbanization. As on Bermuda, this usually occurs at the expense of those unique, specialized forms that give a region its particular character. If we exchange the richness of our natural heritage for crabgrass and starlings, we shall be the poorer for it. ☐

America's National Parks

Their Principles, Purposes, and Prospects

by Joseph L. Sax

A Natural History Special Supplement October 1976

"It's not just another American convention hotel. . . . It's a great American castle. . . . All your worldly needs are provided for . . . when you go to the barber or the hairdresser or the gift shops. . . . This isn't no-man's-land. Or primitive wilderness. This is civilization."

Yosemite National Park is not exactly civilization, despite these advertising claims of Music Corporation of America, which took over the park's concessions in 1973. Like a number of other major recreational developers, MCA in recent years began looking to the national parks as a great unexploited resource of one of America's fastest-growing industries. The National Park Service has thus been importuned to allow the building of new hotels, improved roads, ski developments, aerial tramways, and a host of other such facilities. These proposals raise one of the perpetual issues in our public lands policy—the purpose of the national parks. Although "the national parks idea" is a familiar phrase, the governing statutes speak in very general and unrevealing language. The founding of the parks is itself shrouded in a good deal of mystery, but it is there that our search must begin.

In the midst of the Civil War, on June 30, 1864, President Lincoln signed a bill granting Yosemite to the state of California for "public use, resort and recreation." The national parks were born at that moment. There was no tradition of great scenic parks anywhere in the world, there was no organized public movement in favor of parks, and Congress did not seem to have any particular interest in the idea. Even the most assiduous scholarly efforts over the years have turned up only fragmentary suggestions of the notion in the writings of figures such as Jefferson and Thoreau.

The lands themselves were barely known. The October 1859 issue of *Hutchings California Magazine* recounted the details of a voyage into the then remote Yosemite Valley. Visitors had to take a boat from San Francisco to Stockton, followed by a 16-hour stagecoach ride to Coulterville, and finally a 57-mile, 36-hour trek by horse and pack mule into the valley.

Scarcely any definite knowledge exists concerning the establishment of Yosemite. A bill to turn the land over to California, to be held by it as a public park, was introduced in Congress by Senator John Conness of California. Conness said that he was putting the bill forward in response to a request from some constituents, whom he described only as gentlemen "of fortune, of taste and of refinement." A letter to Conness from Israel Ward Raymond, recommending the reservation of Yosemite, has been preserved; all that is

Yosemite Valley, ca. 1880 Culver Pictures

Yosemite Valley, 1887
Culver Pictures

Jessie Benton Frémont, ca. 1850 — Bettmann Archive

Galan Clark, 1909 — AMNH

known of Raymond is that he was the California representative of the Central American Steamship Transit Company.

Others who are believed to have supported Raymond's suggestion were Jessie Benton Frémont, the wife of John C. Frémont and the daughter of Senator Thomas Hart Benton; Galen Clark, a pioneer who lived in the Yosemite Valley and became its official greeter and guardian; Thomas Starr King, a well-known Unitarian preacher and author, who had written vivid descriptions of Yosemite in 1860 and 1861; Josiah Dwight Whitney, the chief of the California Geological Survey; Judge Stephen Field; John F. Morse, a San Francisco physician; and Frederick Law Olmsted, who in 1863 had come to California to manage the Mariposa mining estate, following one of his periodic clashes with the bureaucracy.

Although the Yosemite legislation set a unique legal precedent, little is known of its background. The language of the bill is taken directly from the letter that Raymond wrote to Conness, yet all it says by way of explanation is that "it is important to obtain the proprietorship soon, to prevent occupation [of the valley by homesteaders] and especially to preserve the trees in the valley from destruction." The bill was not debated in the Congress even though it was the first time that federal land had been dedicated to a nonutilitarian purpose, a policy that would subsequently be seriously, although unsuccessfully, challenged in the Supreme Court on the ground that the federal government was without authority to promote conservation and recreation. Not surprisingly, the statute contains no hint of what (if anything) Congress had in mind about the kind of recreational experience it thought visitors to Yosemite ought to have or about the conflict between preservation and use, although, as we shall see, that was already becoming an issue at popular vacation resorts such as Niagara Falls.

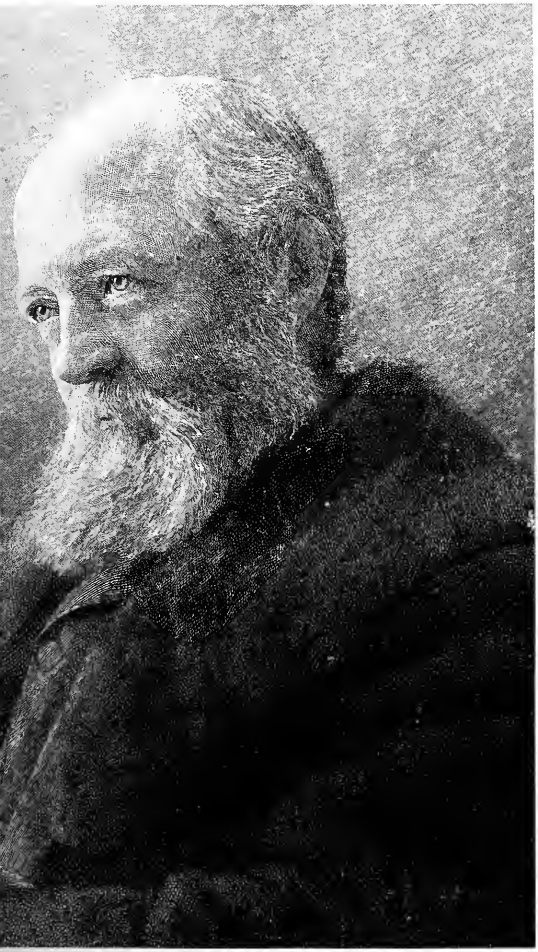
We shall never know exactly how Congress was induced to take so unprecedented a step in fashioning a new public policy, but the explanation probably lies in the influence enjoyed by those who supported the Raymond letter. Josiah Dwight Whitney, whose writings evidence a powerful attraction to places of scenic grandeur, was the scion of a prominent American family that had founded a great mercantile house and given three presidents to Yale. Whitney knew Conness, who, as a member of the California legislature, had written the law creating the California Geological Survey, which Whitney headed. He also knew Judge Field and Thomas Starr King, whose church he attended. Whitney's brother-in-law, who was secretary of the Califor-

nia Steam Navigation Company, may have been the link between Whitney and Raymond. A letter emanating from these sources was nothing less than a message from the leaders of San Francisco society and would inevitably be given more than ordinary attention.

Many have assumed that Frederick Law Olmsted was the theorist behind the creation of Yosemite National Park, but no evidence exists to suggest that a theory preceded the establishment of the park at all. Olmsted probably was one of the gentlemen of taste, fortune, and refinement to whom Conness had referred, and it is true that immediately upon the creation of the Yosemite Park, Olmsted was named chairman of its board of commissioners. Laura Wood Roper, Olmsted's biographer, calls him "the unsung theoretician of the national parks movement" because in 1865 he wrote a report that "formulated the philosophic base for the establishment of state and national parks."

This report has a history as uncertain as that of the Yosemite legislation. The first and obvious point is that it was not written until the year after Yosemite was established. After being appointed head of the board of commissioners, Olmsted drafted the report to articulate his views on the purpose of the park—and on the measures to be taken to assure the fulfillment of that purpose. But the report was suppressed, presumably

Culver Pictures



Frederick Law Olmsted Culver Pictures

by Whitney, because it sought state funds that might have cut into the Geological Survey's appropriations. According to Laura Wood Roper, who discovered the report in 1952, there is no evidence that anyone knew its contents during the eighty-seven years of its disappearance. There were only fragmentary references to it in the press, and park advocates seem never to have relied upon it. Olmsted may have been not only the unsung but also the unknown theoretician of the movement for national parks.

Olmsted's curious position necessarily raises the question of the origin of support for the creation of the park system. Speaking of places like Central Park in New York and the Bois de Boulogne in Paris, he once made a statement that was equally true of the national parks:

> Parks have plainly not come as the direct result of any great inventions or discoveries of the century. They are not, with us, simply an improvement on what we had before. . . . The movement . . . did not run like a fashion. It would seem rather to have been a common spontaneous movement of that sort which we conveniently refer to the "Genius of Civilization."

Yet something about the notion of creating the parks must have struck a responsive chord in a great many people, for numerous independent groups of citizens in various places, a lot of writers and journalists, and many people in Washington joined in a single thought—with the result that by 1916, when the National Park Service was established, there were already fourteen national parks in existence.

There has been a good deal of searching for deep meaning in the scanty information surrounding the establishment of Yosemite and Yellowstone and the other early parks. But the most likely explanations are pretty straightforward. In this period of relentless disposition of the public domain, it was reasonable to fear that even the most magnificent scenic sites might soon be turned over to the plow and to the destructive grazing practices that John Muir immortalized in the phrase "hoofed locusts." The pressures for private settlement were accompanied by the prospect of tourism. By 1869, more than eleven hundred visitors had come to Yosemite.

For all its remoteness, exactly the same prospect was in store for Yellowstone, established eight years after Yosemite. It did not take much imagination to realize that the area's rock formations and geysers, so fantastic that early reports of them were widely disbelieved, would become one of the world's great attractions just

as soon as decent means of access could be arranged.

Part of the mythology of Yellowstone is that the idea for the park was conceived by one of the area's early exploratory parties at an after-dinner campfire in 1870. One member of the group is supposed to have suggested a money-making scheme that involved land claims near the geysers, when another interposed to say that private ownership of so wonderful a region ought never to be countenanced; that it ought to be set apart by the government and forever held for the unrestricted use of the public. "This higher view of the subject," according to Hiram Chittenden in his early book, *The Yellowstone National Park*, "found immediate acceptance. . . . It was agreed that the project should be at once set afoot and pushed vigorously to a finish."

The story is an attractive one, but it has been put in proper perspective by the scholar Hans Huth. In his book *Nature and the American*, Huth reports the discovery of some letters written in 1871 by A.B. Nettleton, an agent for the Northern Pacific Railroad Company. Nettleton passed on a suggestion which struck him "as being an excellent one, viz: Let Congress pass a bill reserving the Great Geyser Basin as a public park forever. . . . If you approve this would such a recommendation be appropriate in [the] official report [of the U.S. Geological Survey]?" Subsequently, the Northern Pacific became the principal means of access to Yellowstone and its first major concessionaire.

The recognition that Yellowstone and Yosemite would soon become places of great public attractiveness created an urgent sense that means must be taken to protect these treasures from destruction—a concern that was by no means hypothetical. Only a few years after Yellowstone National Park had been established, and before the federal government was yet fully in control of its acreage, an official report lamented that

> hunters have for years devoted themselves to the slaughter of game, until within the limits of the park it is hardly to be found . . . the ornamental work about the crater and the pools had been broken and defaced in the most prominent places. . . . The visitors prowled around with shovel and ax, chopping and hacking and prying up great pieces of the most ornamental work they could find; women and men alike joining in the barbarous pastime.

A similar concern had received wide publicity in regard to Yosemite. In 1854 some quick-money promoters visited the Mariposa Grove and denuded several of the sequoia trees of huge portions of their bark,

Hunters in Yosemite National Park Service

Walter Petit National Park Service

which they shipped to London to be exhibited for a fee. Ironically, the size of the trees from which the bark came was, to Europeans, so large as to be beyond belief, and the exhibition, thought to be a fraud, was a financial failure.

The callous misuse of these natural marvels was widely reported and sympathetically attended to, doubtless because there already existed at least one famous example of a great scenic area that had *not* been preserved as a public park and had suffered badly as a result.

Until the beginning of the automobile era, the most famous and popular tourist attraction in the United States was Niagara Falls. Beginning in 1806, the land around the falls began to be sold into private ownership, and by mid-century two evil consequences of private acquisition were already notorious. Entrepreneurs, to take advantage of the water power, had leveled large areas, stripped away the magnificent native foliage, and built a succession of claptrap buildings, factories, and shops that made Niagara one of the earliest victims of American cityscape blight. At the same time, swarms of petty swindlers took up posts at every point near the falls; tourists were importuned, cajoled, lied to, harassed, and abused by hack drivers, landowners, and every sort of self-appointed guide. By the 1860s not a single point remained in the United States from which the falls could be viewed without paying a landowner an entry fee. Niagara was already a well-known lesson when the first western parks were being created, although it was not established as a public reservation until some years later.

The idea of national parks was not only a natural response to the unhappy experience of Niagara, it also harmonized with a principle that was at the very crest of its influence in American public-land policy. The Yellowstone-Yosemite era was the period of the free-land policy, of the Homestead and Desert Land Acts. Every American family was to have the opportunity to own its farm free of monopolization by the rich. The application of that principle to the great scenic wonders could not be realized by granting a sequoia grove or Grand Canyon to each citizen. But it was possible to preserve the great scenic wonders and prevent their appropriation by private interests by holding them as public places to be used and enjoyed by all.

Olmsted put forward exactly that idea in his 1865 report. Those who are rich enough, he said, reserve for themselves rural retreats as large and luxurious as those of the European aristocracy. They take the choicest natural scenes, and the means of recreation they provide, as "a monopoly of a very few, very rich

Mark Twain Tree for AMNH, 1888 National Park Service

General Noble Tree, 1893 National Park Service

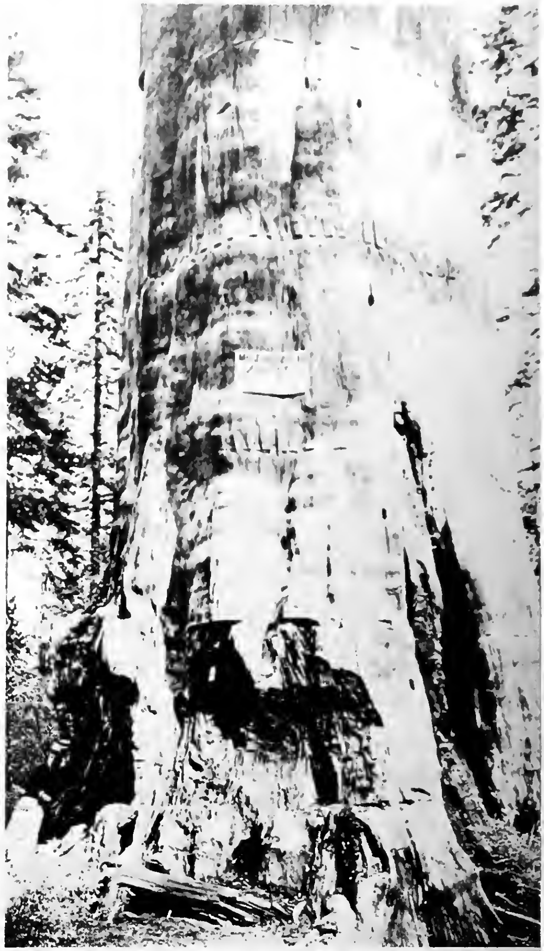
people." Unless government intervened to keep the nation's scenic grandeur in the public domain, "all places favorable in scenery to the recreation of the mind and body will be closed against the mass of the people."

To a reader of Olmsted's report, the most striking fact is that while the parks movement may have been initiated *by* the elite, it was certainly not *for* the elite. It is at once obvious why Olmsted's kind of park policy commended itself to a Congress that had recently enacted the Homestead Act. Jeffersonian idealism and a practical concern with preventing despoliation of great natural resources conjoined to make the establishment of the national parks a far less surprising decision than it might at first appear. And, of course, proposals to preserve scenic places followed a period of romantic idealism that had swept the country—the religious naturalism of Thoreau and Emerson, romanticism in the arts, and nostalgia for what was obviously the end of the untamed wilderness, already in submission to the ax, the railroads, and the last campaigns against the Indians.

The parks also appealed to a tenacious American desire to measure up to European civilization. What little discussion one finds in early congressional debates over the parks is full of suggestions that our scenery compares favorably to the Swiss Alps and that we can provide even more dazzling attractions for world travelers. In the awesome scenery of the mountainous west, America had something with which it could at last compete with Europe on an equal plane.

Beyond this, the parks movement, both in its beginnings and later, was extraordinarily fortunate in the quality of its leadership. Simply to mention three of the people most prominently associated with the national parks during their first half-century—Olmsted, John Muir, and Stephen Mather—is to identify three of the most effective shapers of public opinion the country has ever produced. They make an interesting trio—each very different from the other, yet each an American prototype.

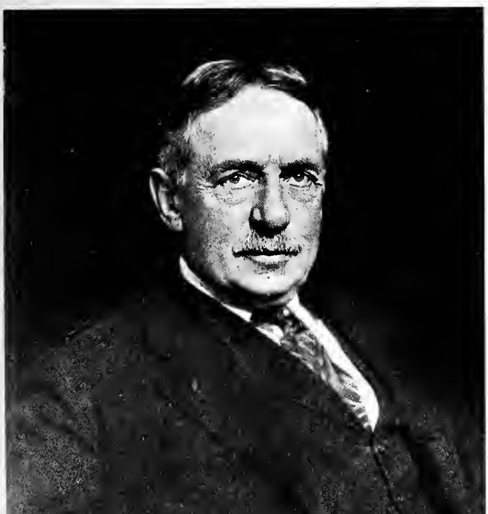
Olmsted was the model of a respected establishment figure. He distinguished himself by his intellectual attainments as well as by his administrative and organizational ability. His books on the pre-Civil War South brought him early and lasting prominence. His leadership during the war, as executive secretary of the U.S. Sanitary Commission (predecessor of the Red Cross), together with his struggles with the Tammany mob over the management of Central Park, established him as a man of affairs. His success as a founding figure in landscape architecture gave him enormous professional



Mother of the Forest Tree, ca. 1890

California Dept. of Parks and Recreation


TR and John Muir, Yosemite, 1903 Culver Pictures


Fairfield Osborn AMNH

stature. And, not least, his comfortable background and social standing gave him easy access to the rich and powerful.

Although Olmsted is associated with the national parks principally as a creator of ideas, he was plainly an effective shaper of events as well. He was responsible for the organization and direction of the long and difficult campaign for the establishment of a park around Niagara Falls. As early as 1869 he began meeting with influential opinion makers to plan how to combat the desecration of the falls. He directed the preparation of many magazine articles and of a petition that contained as dazzling a list of signers as any such document has ever had, including the signatures of all the sitting justices of the Supreme Court. The Niagara effort ended in success in 1883 when a bill authorizing creation of a state reservation was enacted by the New York legislature. Olmsted was plainly one kind of American hero, an idealist who could translate his ideas into effective political action.

John Muir was a very different, but at least equally appealing, figure. Muir embodied a great many of the personality characteristics of the western fantasy hero: a lonely, independent, self-reliant figure, sure of his values and uncorrupted by the softening ways of urban life. One can hardly think of the national parks without bringing to mind those photographs of John Muir, lean and austere, as unyielding in appearance as in principle, framed against the no less rugged peaks of the Sierras.

Muir was a folk-figure, but beyond that he, too, was a skillful shaper of public opinion. Unlike Olmsted, who wrote little after his early books on the South, and that with difficulty and awkward stiffness, Muir was a master of vivid, descriptive prose. He made the mountains come alive for millions to whom a voyage to California was a hoped-for, once-in-a-lifetime aspiration.

John Muir was no less impressive in person than he was in print. His landmark tour of the high country with Teddy Roosevelt, a public relations triumph of the highest order, was only one of many such experiences. Robert Underwood Johnson, editor of the influential *Century* magazine, describes in his autobiography an 1889 meeting with Muir and a subsequent tour of Muir country under the master's tutelage. Thereafter, *Century* opened its pages to Muir, who used them to very great effect in the later battles over Yosemite.

Stephen Mather was in no sense a founder; he did not become a figure in national park history until 1915, but as the first director of the National Park Service, he dominates the whole first era of the national parks

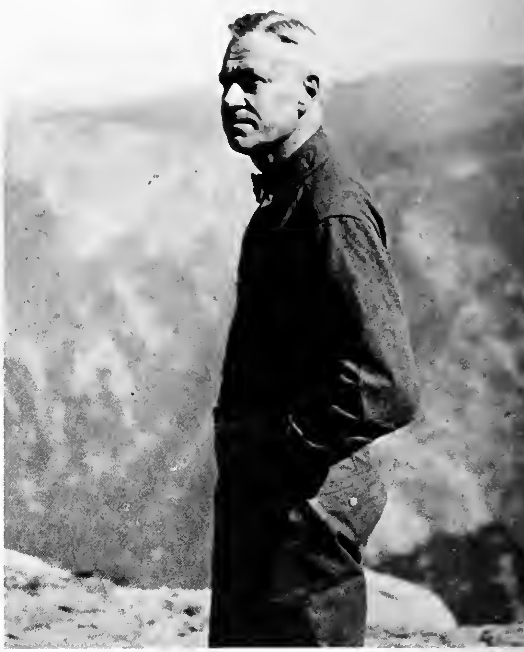
system as a governmental institution. A millionaire businessman, Mather was a disciple of John Muir and an indefatigable admirer of the Sierra Nevada mountains. And he was the very model of an American salesman. He brought to the park service the identical traits—enthusiasm, imagination, a keen public relations sense, lavish spending, and an eye for good young talent—that had made him a commercial success.

Mather perceived that any public enterprise needed friends in the legislature, frequent and continual praise in the press, and the goodwill of vast numbers of ordinary people. He set out to achieve each of those goals and did so with incomparable success and a generous dose of the personal flair and color that always made for good publicity. When the government would not make money available for the construction of the much needed Tioga Road in Yosemite, he used his own funds. He drove around the parks in a big black motorcar with a special and much-photographed license, "US NPS 1." And he went from park to park personally greeting astonished tourists. He was the perfect opposite of everything that is encompassed in the expression "faceless bureaucrat."

Perhaps Mather's most characteristic, successful, and widely known achievement occurred in 1915 as part of an effort to garner support for the upcoming congressional consideration of the bill to create a National Park Service. The need for such legislation had long been recognized, for every one of the fourteen parks then in existence was being run as a separate entity. There was no central park policy or budget, and the parks, having been managed to a substantial extent by the U.S. Cavalry, were in urgent need of both money and intelligent coordination. Bills had been introduced since 1910, and Congress had held hearings twice, but no law was brought to the point of enactment until Mather came on the scene.

To set the stage for the coming legislative session, Mather decided to have a little outing with some opinion leaders, to imbue them with the mystique of the parks and persuade them to put their influence behind the bill to establish the National Park Service, all the while having a splendid time in the high country. Among Mather's guests were Fairfield Osborn, head of The American Museum of Natural History; Emerson Hough, one of the most renowned writers of the day; Fred H. Gillett, the future Speaker of the House of Representatives and the ranking Republican on the Appropriations Committee; Gilbert H. Grosvenor, editor of *National Geographic*; E. O. McCormick, vice president of the Southern Pacific Railway; and Burton Holmes, a travel lecturer. For nearly two weeks, the

Emerson Hough, 1902 — New York Public Library



Stephen Mather — Culver Pictures

distinguished party saw the best of the Sierras. As one magazine article put it,

> Mather had spared no expense in outfitting his guests. Each man had a new sleeping bag and air mattress which combined to make a classy and perfectly comfortable wilderness bed. There were horses to carry the men and mules to carry the supplies, which included a bountiful stock of fresh fruit, fresh eggs and other delicacies. . . . As camp was pitched, Tie Sing, a marvelous camp cook whom Mather had borrowed from the U.S. Geological Survey for the occasion, would construct a dining table, usually out of logs, and then . . . a linen table cloth would show up, and real napkins for everybody. Tie Sing would put together his collapsible stoves and calmly prepare soup, lettuce salad, fried chicken, venison and gravy, potatoes, hot rolls, apple pie, cheese, tea and coffee.

Just as Mather had hoped, generous support and lavish publicity in favor of the parks began to roll out; the April 1916 issue of *National Geographic* was wholly devoted to the national parks. By August 25, right on schedule, President Wilson signed the bill creating the National Park Service and Mather became its first director.

As one reviews the early history of the national parks, what at first seems an astonishing anomaly begins to take shape as a series of events very much in tune with contemporary American attitudes, helped along mightily by friends of extraordinary skill, ability, and influence.

The attractiveness and success of the idea of creating national parks, however, is easier to understand than the content of "the national parks idea." In recent years, as tourism has grown, the parks have been at the center of many controversies over the question, What kinds of recreational uses ought the national park system serve? All agree that the parks are for public use and that their great scenery must be protected from destruction. To recognize these fundamentals, however, is hardly to begin to deal with the questions raised by the competing claims of the many constituencies of park users. Should hotels and other accommodations be permitted within the parks or should they be located outside the park boundaries? Should the park service put in more camping facilities and supportive services to accommodate the ever growing number of people who want to use the parks or should access and use be limited so as to provide an uncrowded recreational

Yosemite Falls, ca. 1870 Culver Pictures

Camping Trip, Sierra Nevada, 1915

Gilbert H. Grosvenor © National Geographic Society

experience? Is it proper to open the parks to snowmobiles or elaborate downhill skiing operations? Other, less obvious questions arise, such as, Should the park service permit concessionaires to advertise to attract business conventions to the parks—even in the off-season when their facilities are not otherwise full?

The usual place to look for answers to such questions is in the history of congressional enactments establishing the national parks, for it is Congress that is supposed to make national park policy. A detailed examination of that history, however, would not only be tedious but fruitless because in the many decades that have passed since Yosemite was first established, Congress has never resolved or even grappled with these hard questions.

Congress long ago established that the parks should be protected against destruction and that they should be made available to the ordinary citizen, rather than preempted as a preserve for the rich. But to say that the parks are for the people is not necessarily to say that they are for intensive mass recreational use.

All we really know about congressional intent is that there were some activities that Congress did not want in the parks. With rare exceptions, mining and dam building have been prohibited in the parks for many years. Unlike the national forests, the parks have not

been set aside for multiple use—recreation and grazing, timber harvesting and wildlife conservation. Gifford Pinchot, then chief forester of the United States and a spokesman for scientific forest management, fought and lost that battle against the conservationists—he called them "nature fakirs"—in 1916. In that year, despite Pinchot's best efforts, Congress enacted the only general policy mandate it has ever issued for the parks, and it continues to be the central statement of park policy today. The so-called Organic Act is a clear repudiation of those who wanted the parks to be used for industrial purposes as well as conservation and recreation, but it says nothing about the balance to be drawn between preservation and use so as to resolve the issues that are being raised today by MCA and other aggressive concessionaires. The Organic Act simply says:

> The [National Park Service] shall promote and regulate the use of the Federal areas known as national parks . . . by such means and measures as conform to the fundamental purpose of said parks . . . which is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.

Conservation for posterity is the stated purpose of the parks, but that hardly tells us whether ski lifts, winterized roads, and improved hotels are appropriate. A more recent law, enacted in 1965, adds nothing to our understanding; it merely says it "is the policy of the Congress that such development [in the parks] shall be limited to those that are necessary and appropriate for public use and enjoyment of the national park area in which they are located and that are consistent to the highest practicable degree with the preservation and conservation of the areas." The intent of Congress is simply not known. It would probably be more accurate to say that there does not exist any explicit intention.

To understand national parks legislation, we must adopt a rarely taken approach. In passing laws, Congress often does not initiate the ideas that it transforms into statutes; rather it acquiesces in, and associates itself with, the views of private citizens who have urged those ideas on it. Without fully exploring those ideas for itself, Congress acts to give legitimacy to a point of view that has captured the imagination of the public. It would be impossible to appreciate the legislative battles in England over factory reform legislation in the

Hutchings Hotel, Yosemite Valley, 1879 Historical Pictures Service

early decades of the Industrial Revolution without understanding the impact on public thought of an Adam Smith, on the one hand, or of social-reform novelists such as Charles Dickens and Elizabeth Gaskell, on the other. Nor, as scholars of constitutional law have long understood, can cryptically stated provisions in the Bill of Rights be appropriately interpreted without a thorough knowledge of the historical experience out of which they grew.

Rather than merely picking over the sterile fragments of official history that have been left us, we should turn our attention to the aspirations of those who devoted their lives to persuading the American public of the efficacy and importance of parks. Within that small but influential group, one figure, Frederick Law Olmsted, stands out above all others. It would be impertinent to insist that Congress must be charged with having mandated Olmsted's beliefs into legislation, and it must be noted, with sadness, that Olmsted's ideas have been substantially betrayed in each of the places he worked to save—Yosemite Valley, Niagara, Central Park. But it is not too much to suggest that the values he sought to advance in his professional life provide an appropriate background against which to test our national parks policy.

The key to understanding Olmsted's thought is the recognition that he had more than merely a theory about recreation—he had a philosophy of leisure. His writings reveal that he held the same view of urban parks as of the national parks and, indeed, the same view of suburban residential developments as he did of urban and national parks. Every important idea in his 1865 Yosemite Report also appears in his work on Central Park, Niagara Falls, and the other places to which he turned his formidable talents.

Olmsted was not just a builder of parks; he was the author of a distinctive theory about the role parks ought to play in a democratic society. Nothing was further from his view than the now widely held idea that in a democracy the sole acceptable park policy is to facilitate access for the greatest number of people that can be accommodated and then to establish whatever activities the popular sentiments of the hour appear to demand. Instead he held to what might elaborately be called an intertemporal theory of democratic legitimacy: that the justification for the use of the parks must be sought in the long-term judgment of the people and that there was a legitimate role for leadership in a democratic society.

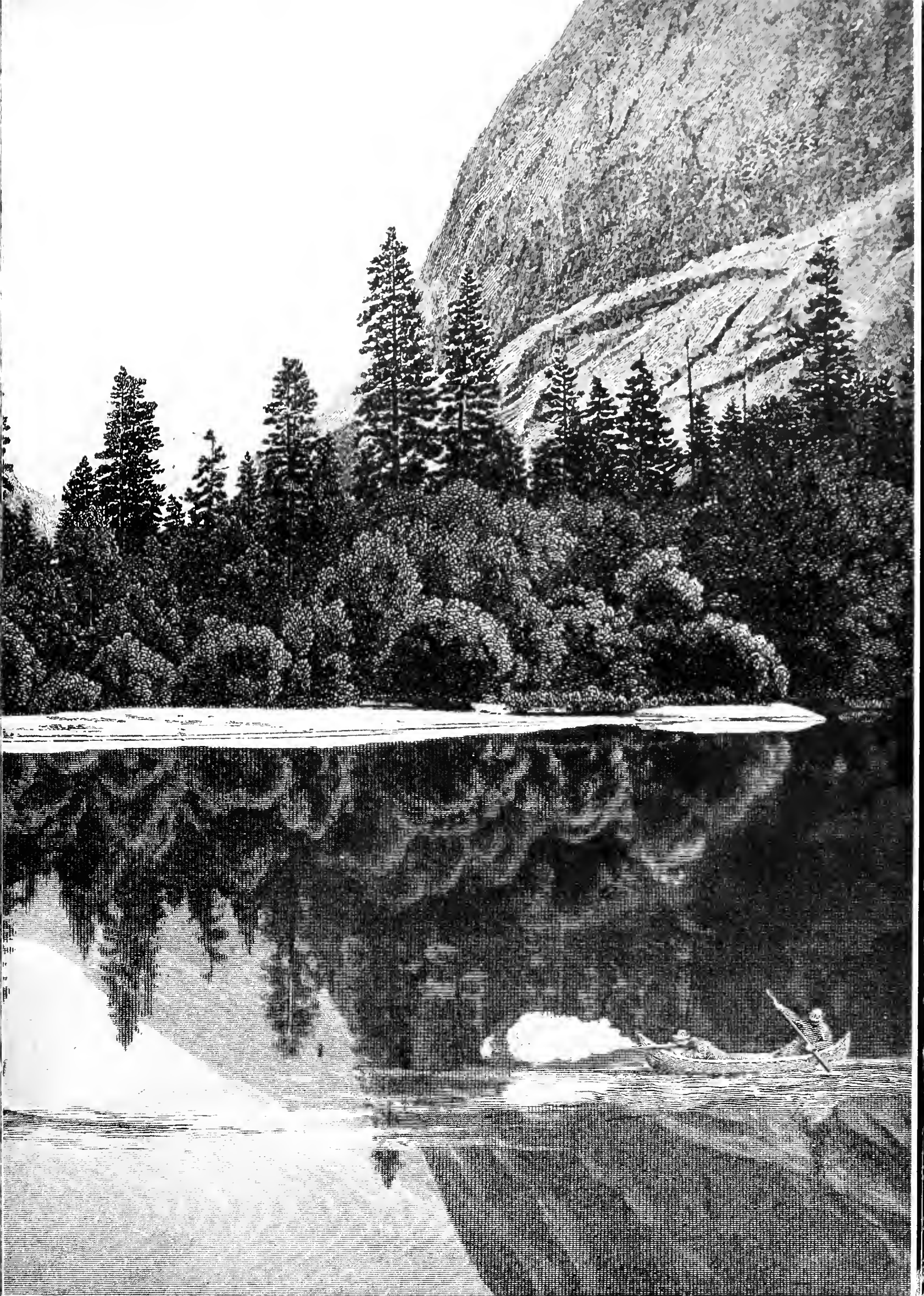
Olmsted never had the slightest doubt that he would be vindicated by history. In what was probably the most revealing statement he ever made, he reflected late in

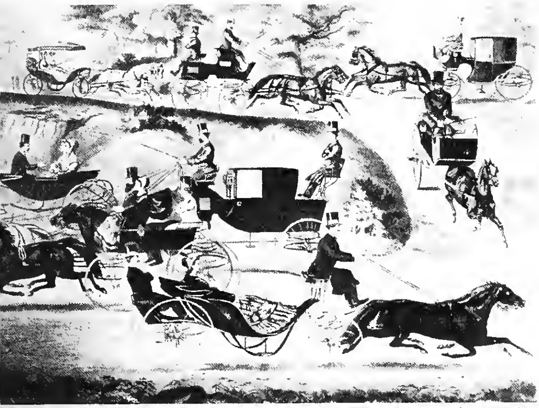
Cathedral Rocks, Yosemite, 1877

Culver Pictures

Overleaf: Mirror Lake, Yosemite, 1872

New York Public Library





Carriages in Central Park, ca. 1860 Bettmann Archive

1857. CITY OF NEW YORK. 1893.

DEPARTMENT OF

PUBLIC PARKS

Central ◇ Park.

FOUNDED 1857.

CENTRAL PARK CARRIAGE SERVICE, ORGANIZED 1869.

Carriages will leave the Scholars' Gate, 59th Street and Fifth Avenue, and the Merchants' Gate, 59th Street and Eighth Avenue, making the circuit of the Park, at brief intervals, and MAY BE TAKEN ANYWHERE on the road.

Fare for Each Passenger for the round trip, **25** cents. Tickets must be purchased of the Starter, and they entitle passengers to be put down and taken up at the Museum of Natural History, Mt. St. Vincent, Museum of Art and the Terrace Bridge.

Carriages in going take the West Drive, in returning the East Drive, thus making the tour of the Park. In going, you are driven past the Museum of Natural History in Manhattan Square, and the great Croton Reservoirs. The tower at the lower Reservoir is the Belvedere, from which a fine view of the Park and the surrounding city may be obtained. In returning, carriages stop at Mt. St. Vincent, Museum of Art and the Terrace Bridge.

Bettmann Archive

his life that there were "scattered through the country seventeen large public parks . . . upon which . . . I have been engaged. . . . They are a hundred years ahead of any spontaneous public demand." To the charges, made repeatedly during his career, that he was what we would call an elitist, Olmsted had a two-word reply—Central Park. The great achievement of his life was the design of a park that met no extant public demand because no such park had been conceived of until he created it. He said of Central Park, "A large part of the people of New York are ignorant of a park, properly so-called. They will need to be trained to the use of it. . . ."

When a question arose in Central Park's early days about its remote location from the great bulk of the populace, so that it was accessible mainly to the affluent, Olmsted coolly responded that the park had been designed to be in the middle of the city when New York doubled its size. Long before Manhattan became a treeless vista of vast towers that dwarfed the individual, Olmsted had the dazzling idea that the New York resident of the future would appreciate nothing so much as a rural vista. And in 1865, writing about then virtually unknown Yosemite, he could calmly and confidently talk about visitors in the "millions" that the next century would bring.

His vision, however, was not merely an exercise in prophecy. He saw the popular demands of the moment as being principally the product of self-interested manipulation by those who had much to gain by a determined shaping of public opinion to their own ends. In his Yosemite Report, he observes that the governing classes of Europe had preempted the great scenic resources to their own exclusive use not simply out of selfishness but because they had persuaded themselves that the masses were incapable of rising above a brutish existence. Thus they thought it was pointless to make available a form of leisure designed to elicit from the ordinary citizen the exercise of the "esthetic and contemplative faculties."

The product of such a view was a policy that treated ordinary people as passive objects to be entertained at the most superficial level. The mass recreation that existed was not, in Olmsted's view, a response to popular demand, but rather the calculated provision by those in control of a program of "bread and circuses." The governing elite, Olmsted complained, think it desirable "so far as the recreations of the masses of the nation receive attention from their rulers, to provide artificial pleasure for them, such as theatres, parades, and promenades where they will be amused by the equipages of the rich and the animation of the crowds." Of course,

those who profited from the provision of mass entertainment were more than happy to make such passive "artificial pleasures" available.

The great test case for Olmsted was Niagara, for the campaign to "save" Niagara was, after all, a battle in service of a place that was the single most popular tourist attraction in the United States. Four years before the New York legislature authorized acquisition of the land bordering Niagara Falls, Olmsted responded to criticisms from those who had been making money providing tourist attractions and who thus opposed the park. According to them, Olmsted said, the flow of tourists had continued to grow despite all the developments that he and his associates so vigorously condemned.

> Were all the trees cut away, quarries opened in the ledges, the banks packed with hotels and factories, and every chance open space occupied by a circus tent, the Falls would still, these think, draw the world to them. Whatever has been done to the injury of the scenery has been done, say they, with the motive of profit, and the profit realized is the public's verdict of acquittal.

Just as fourteen years earlier, in the Yosemite Report, he had attacked those who condescended to the public by providing them with passive entertainments, here he made explicit his conviction that the public is perfectly capable of being led and can be induced to acquiesce in that which is put before them. His response was that "the public has not had the case fairly before it. The great body of visitors to Niagara come as strangers. Their movements are necessarily controlled by the arrangements made for them. They take what is offered, and pay what is required with little exercise of choice. The fact that they accept the arrangements is no evidence of their approval."

To Olmsted, mere public acquiescence was not the hallmark of democracy. He was sophisticated enough to see that Niagara as it was represented the imposition of a standard of taste no less than Niagara as he sought to make it. In the former case it embodied the standard of taste imposed by those whose goal was to exact as much money as possible from the tourist. In the latter it would reflect the aspiration of those who believed that an experience of quiet solitude in a setting of untrammeled natural scenery could attract and stir the contemplative faculty in even the most ordinary citizen.

The proof, of course, is now before us. Niagara lost not a whit of its popularity after the state park was created and the most obtrusive structures and most stri-

May Party, Central Park, ca. 1900 Culver Pictures

The Mall, Central Park, 1885 New York Public Library

Niagara Falls, 1869 New York Public Library

Riverbank, Niagara Falls, 1880 Historical Pictures Service

dent hawkers removed from its premises. The national parks, kept largely untrammeled, have grown in popularity with each passing decade. The wilderness system has proved itself beyond the most extravagant expectations of those who struggled for its creation against continued charges of antidemocratic elitism. At the same time, the landscape is strewn with the remnants of once-popular resorts developed down to the last acre of available land. Is there anyone today who would trade Glacier National Park or the Everglades for Atlantic City, or who, recoiling today from the power lines and neon in the vicinity of Niagara, does not believe that its environs ought to have been reserved in the national parks model a century and a half ago?

As Olmsted demonstrated, the question in a democratic society is not the acceptance or rejection of what the people want. People get the recreation that imaginative leadership gives them. No one wanted Disneyland any more than they wanted Yosemite National Park. The question is whether there is a legitimate place in this society for recreation that is not likely to be sufficiently profitable for private entrepreneurs.

It is to this question that Olmsted provided the distinctive answer that lies at the heart of his achievement. The essence of recreational policy in a democratic society, he believed, was the willingness to treat the ordinary citizen as something other than a passive customer to be managed and entertained. Olmsted based his theory of recreation on what he called "a faith in the refinement of the republic," a faith in the possibility of liberation from self-interested manipulation.

Many years ago, he said, before Niagara had become a tourist industry, "a visit to the Falls was a series of expeditions, and in each expedition hours were occupied in wandering slowly among the trees, going from place to place, with many intervals of rest. . . . There was not only a much greater degree of enjoyment, there was a different kind of enjoyment. . . . People then were loath to leave the place; many lingered on from day to day . . . revisiting ground they had gone over before, turning and returning."

All that had changed by the 1870s; the visitor had become the object of prepared entertainment. "Visitors are so much more constrained to be guided and instructed, to be led and stopped, to be 'put through,' and so little left to natural and healthy individual intuitions. The aim to make money by the showman's methods . . . is so presented to the visitor that he is forced to yield to it, and to see and feel little else than that prescribed to him."

Leisure was the counterpoint of life for Olmsted. It was the occasion for putting all the busy, filled hours

of daily routine into perspective. He fully appreciated that in the hurried pace of urban life in an industrial age, nothing was more essential than occasions for testing the importance of one's daily tasks against some permanent standard of value. Like other observers of the industrial world, he perceived the dangers of a life of meaningless activity where all that had stood for permanence and value in the traditional world had been swept away—the centrality of the church, continuity of place and position, the binding forces of tradition itself.

Unlike some great scholars of industrialism, Olmsted was fundamentally hopeful. He believed it was possible to engage the contemplative faculty by inserting in the physical setting of the modern world a rhythm of nature as a standard of permanent value.

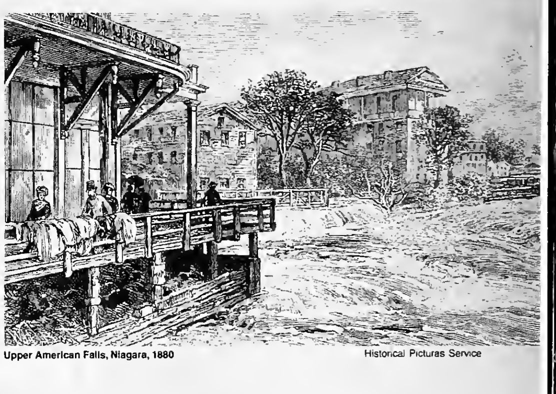
Everywhere in his work one basic idea is dominant—the idea of contrast. Modern man must have an opportunity to contrast the pace, setting, values, and activities that dominate his daily life. He must be permitted to stir the contemplative spirit by being provided an experience that literally removes him from all the forces that impel his daily routine.

> We want a ground to which people may easily go after their day's work is done, and where they may stroll for an hour, seeing, hearing, and feeling nothing of the bustle and jar of the streets, where they shall, in effect, find the city put far away from them. We want the greatest possible contrast with the streets and the shops and the rooms of the town. . . . We want, especially, the greatest possible contrast with the restraining and confining conditions of the town . . . a simple, broad, open space of clean greensward, with sufficient number of trees about it to supply a variety of light and shade . . . to completely shut out the city from landscapes. . . . What we want is tranquility and rest to the mind.

When Olmsted spoke of "pleasure or recreation," he had something quite different in mind from what we commonly comprehend by terms like "recreation." Indeed, Olmsted spent a good part of his life fighting off various attempts to use Central Park for "towers, houses, drinking fountains, telescopes . . . Aeolian harps, gymnasiums, observatories and weighing scales, for the sale of eatables, velocipedes, Indian work, tobacco and segars."

A park full of human improvements will of necessity be a place that reflects the fashions and interests of the moment; it will emphasize and glorify the values of the moment. A natural park has nothing so much as

Maria Spelterini crosses the Great Gorge, 1876 — Bettmann Archive



Upper American Falls, Niagara, 1880 — Historical Pictures Service

Winter at Niagara Falls, ca. 1880 — Culver Pictures

Niagara Falls, 1916 — Bettmann Archive

the quality of timelessness. It stands outside the scale of human achievement.

The provision of parks to make available this sense of contrast led to the second of Olmsted's fundamental premises: his unyielding opposition to artifice. It would be easy to misconstrue this position as simply advocacy of wilderness, but a careful study of his view makes clear that Olmsted had something quite different in mind. He never lost sight of his principle that the parks were to be designed to accommodate large numbers of people without depriving them of the kind of experience for which the areas had been created. Thus in his 1887 Niagara Report he stated the principle as follows:

> Nothing of an artificial character should be allowed a place on the property, no matter how valuable it might be under other circumstances and no matter at how little cost it may be had, the presence of which can be avoided consistently with the provisions of necessary conditions for making the enjoyment of the natural scenery available.

In proposing a detailed plan for the Niagara reservation, Olmsted described his principle of necessary artifice. He thought it quite appropriate, for example, to equip a train stop with toilets, shelters, picnic facilities, and the like. And he further recommended the building of walkways, as well as restorative efforts to combat erosion and restore barren areas.

He was opposed to fancy landscaping, because "it is calculated to draw off and dissipate regard for natural scenery" in favor of an exaltation of human ingenuity. Since his report was a practical planning document, he carefully responded to a variety of developmental proposals. One plan urged that a fine restaurant be built on Goat Island, a wild place just above Niagara Falls. Olmsted conceded that any structure would to some degree obscure and distract attention from the natural scene, but that alone was not sufficient to disqualify it. Rather, he asked, "will the absence of places of refreshment cause such hardship to visitors, reasonably prudent for themselves, as to seriously interfere with the general enjoyment by the public of the scenery?" Noting that a modest drive would bring visitors to hotels and restaurants located outside of the reservation boundaries, he opposed the planned restaurant.

Probably the most revealing expression of Olmsted's approach was his opposition to a proposal to permit people to see the falls without having to leave their carriages. Olmsted was by no means a wilderness advocate, and for him the question of people being asked to walk, rather than ride, through the reservation was

a serious one. Being a professional planner, he always had a highly practical response. In this instance, he began by observing that each carriage took up much more space than a pedestrian, and in a place where as many as 10,000 people a day visited, even in the 1880s, he argued for the exclusion of carriages as an effective means of enlarging the carrying capacity of the park.

But that was not his principal concern. To experience the park as a contrast, to get inside the scenic experience, it was necessary to take some time—to see the falls at length and at leisure. To design the scenic viewing areas to accommodate numbers of carriages would "interpose an urban, artificial element plainly in conflict with the purposes for which the Reservation has been made." The point is a powerful one. There is nothing malevolent in seeing the park from a carriage moving rapidly from one fixed, scenic overlook spot to another, but Olmsted regarded it as an urban experience, a man-dominated experience rather than a timeless experience in which the falls were the overwhelming presence. Niagara, Olmsted insisted, should be managed to encourage people to view the falls "in an absorbed and contemplative way." To such an experience, the carriage is an obstruction.

If there is any perspective that dominates contemporary thinking about the parks, and about recreation in general, it is the consumer perspective. To this viewpoint, Olmsted presents the elevating contrast of a cultural perception of the uses of leisure. To speak of man as the measure of all things is not only to state a cliché but to describe a world in which the rhythm of life is tuned only to the pace of human enterprise. It is not that we are necessarily going too fast, but that we risk losing contact with any external standards that help us to decide how fast we want to go. It is the function of culture to preserve a link to forces and experiences outside of the daily routine of life. Such experiences provide a perspective—in time and space—against which we can test the value, as well as the immediate efficacy, of what we are doing.

Every culture provides institutions that preserve the possibility of perspective. The Sabbath as a day of rest provides the opportunity to infuse the relentless passage of time with meaning. The Constitution, in our legal system, builds a perspective of time into social decision making, which by creating a link with the values that dominated our past acts as a restraining force on the instincts of the moment. And the museum collects the experience of our predecessors in a display of all that has given value to the generations before us who have experienced the joys and travails of birth, growth, and death. In short, culture gives context to

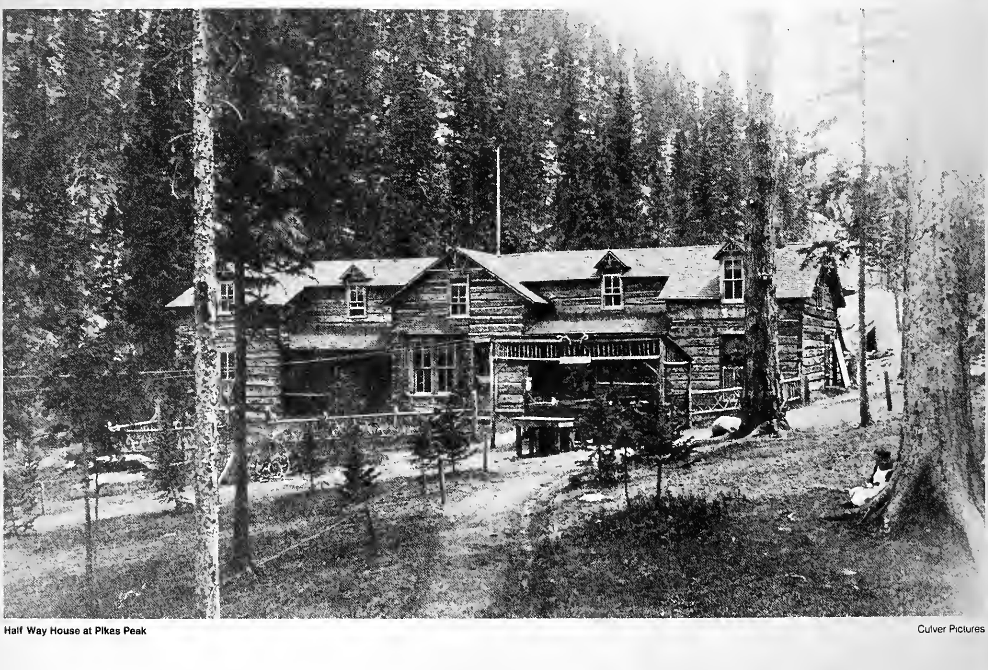
Niagara Falls, ca 1870 Fredric Lewis

Niagara Falls, ca. 1880 Culver Pictures

our lives, and context is the indispensable ingredient for a life infused with value.

This view puts many contemporary park controversies in proper perspective. It is clear that Olmsted would have found a golf course in Yosemite Park an anomaly, not because people do not enjoy golfing in the midst of magnificent scenery or because golf is a less desirable activity than hiking, but because the center of attention would be diverted from the experience of nature to the achievements of man. By the same reasoning, Olmsted had no objection, as such, to building roads and to the use of vehicles in a park. To Olmsted, an issue like roads was not an either/or question but a question of speed and congestion. To build highways so that masses of people could be moved through the parks, catching a glimpse of the scenery as they passed, or to stop here and there to add to their list of "things done" the observation of a famous sight was to misconceive the purpose for which the parks were created.

This perspective tells us a good deal about the kinds of facilities that are appropriate within the parks. There is nothing wrong with having some cabins or hotels within the park boundaries, but they should be designed to do no more than facilitate the opportunity to experience the park's scenery. The park is not an appropriate place to put a masterpiece of human architecture nor is it a place in which to found a distinguished restaurant



Half Way House at Pikes Peak

Culver Pictures

or a mall of fashionable shops; again, not because it is inappropriate for people to enjoy these amenities, but because they divert the visitor's attention to the achievements of man. This is not to say, of course, that one cannot enjoy the scenery during the day and a fine dinner and nightclub afterward; it is simply to say that the purpose of the parks is to draw people out of the routine of daily life, to create a total and encompassing experience, to change the entirety of their pace and permit the rhythm of the park to take over. This is the reason Olmsted said, in his Niagara Report, that if "a costly object of art, like the Statue of Liberty, should be tendered to the State on condition that it should be set up on Goat Island; it would have to be declined, as would a museum or library, worthy as they are."

Here and there in the literature of exploration of the parks there is an explicit statement of the kind of experience that Olmsted sought to engender when he spoke of stirring the contemplative faculty. It is at the heart of the writings of Thoreau and John Muir. It is to be found, more recently, in Colin Fletcher's description of his pioneering two-month walk through the Grand Canyon of the Colorado:

> The rhythm of the rocks beats very slowly, that is all. The minute hand of its clock moves by the millions of years. . . . And if you listen carefully—when you have immersed yourself long enough, physically and mentally, in enough space and enough silence and enough solitude—you begin to detect, even though you are not looking for it, something faintly familiar about the rhythm. You remember hearing that beat before, point and counterpoint, pulsing through the inevitably forward movement of river and journey. . . . And you grasp at last, in a fuller and more certain way than you ever have before, that all these worlds move forward, each at its own tempo, in harmony with some unique basic rhythm of the universe. . . . We all of us experience this oceanic feeling, I think, at some time or other. . . . I felt, now, a sense of common origin and direction. . . . And while it lasted nothing else mattered, nothing else existed.

Fletcher's description, extravagant as it is, nonetheless encompasses the totality of experience that has underlain the impetus for a system of parks—from the limited setting of New York's Central Park to the vast reaches of the great western national parks—the desire to create a setting in which there can be an immersion in the natural scene. From this perspective, it is plain why there has been vigorous objection to the use of

Grand Canyon, 1903 — Culver Pictures

European engraving of western landscape — Culver Pictures

the national parks for conventions, whether or not they take place in the "off-season," and despite the fact that nothing in the nature of a business convention could be said to "impair the scenery." A convention tourist cannot, by the very nature of his or her visit, submit fully to the rhythm of the place.

The same reasoning explains why there has been opposition to downhill skiing developments, but no objection to cross-country skiing in the parks. The distinction has seemed too subtle to persuade some, but it is fully in accord with the Olmsted philosophy. Although one of the most delightful leisure activities, downhill skiing exists today as a magnet sport—drawing large numbers of people together in a small place, making them dependent upon rather substantial mechanisms for transportation to the top of the run, drawing a cadre of professional teachers, spawning classes with elaborate hierarchies of achievers, and turning a great deal of attention to a vast panoply of equipment and clothing. The end product, more often than not, is everything that characterizes an urban assemblage of people—crowds, striving, economic distinctions, feelings of dependence, time pressures, and the like. This is the antithesis of everything that the parks were designed to promote.


Campers, Yosemite Valley, ca. 1870 Culver Pictures


Yosemite Valley, ca. 1870 Sierra Club


Adirondecks, 1888 Culver Pictures

A failure to appreciate that the parks are more than simply undestroyed scenery has led to another controversy—the proposed development of only a tiny fraction, perhaps 1 or 2 percent, of the total park acreage. The difficulty with this argument is that most developments are proposed for the most attractive and most accessible parts of the park. There may be a great deal of unspoiled Yosemite Park outside the valley, but it is to the valley that most visitors come, especially those least familiar with the park.

To permit intrusions in such places, however small in size, is to impair the opportunity to experience the natural scene in the only places that most first-time visitors are likely to see. It is especially ironic that proposals for developments in the park are justified on the ground that they will provide services for the inexperienced, most of whom are leery of the rugged backcountry. Yet if such developments are allowed, the visitor arrives to find that the only area of the park that is easily accessible to him is not the celebrated scene that John Muir depicted, but a congeries of trailers, shops, restaurants, and cabins.

Even this contradiction is not enough to dissuade some developers. They respond that the parks cannot serve Olmsted's aspirations if people do not visit them, and that it is a necessary part of the educational ambition of the park system to bring the people to the parks

so that these timeless areas can begin to work their magic on visitors. Even Stephen Mather once suggested that the parks should set out to attract people by building golf links, tennis courts, and swimming pools.

There is more than a little irony in reviewing today that aspect of Mather's approach to the national parks, for while he spent his life winning friends and popular support for the park system, the measure of his success is that the most serious current problem of the parks is that they risk being loved to death. Indeed, from their very first years, the national parks have grown steadily in use and popularity (except for temporary remissions during wartime and economic depression). And they have grown in use despite the reluctance of the National Park Service, even during its periods of greatest developmental enthusiasm, to build facilities such as golf courses, swimming pools, or tennis courts.

To the extent that the park service has allowed urbanizing influences to dominate park management, as in the Yosemite Valley, a quite different lesson has emerged. It is that the parks become a magnet for those who are seeking the kind of uses that these areas permit. The building of elaborate hotels, shops, and modern campgrounds attracts more and more people in search of the kind of recreation those facilities promote. Of course there are vast numbers of tourists who are in pursuit of what might be called high-intensity urban recreation and who are glad to have it in the striking setting of a Yosemite Valley. And there are many who want to go to any place where many others are going. A few years ago, Bryan Harry, the chief naturalist at Yosemite, said: "People used to come for the beauty and serenity. Those who come now don't mind the crowds; in fact, they like them. They are sightseers, and they come for the action."

The managerial principle seems to be that the parks become whatever the parks are permitted to be. Moreover, those who come to participate in high-intensity recreation inevitably create a demand for the supportive services appropriate to that activity. Olmsted fully understood this. He knew that even with the most sensitive management the parks would attract more people than they could reasonably accommodate at a given time, and in his Niagara Report he explicitly recommended techniques for limiting access. To Olmsted there was nothing inherently democratic about a crowd.

Perhaps the saddest element in the controversy over the national parks is that in a sincere effort to make the parks democratic, we have felt constrained to make them familiar; and in making them familiar, we have threatened to deprive them of their distinctive natural

Yellowstone, ca. 1880

Culver Pictures

Automobile campers, ca. 1920

Culver Pictures

rhythms. Not many years ago, in a policy report now happily no longer the dominant view, the park service was advised that the majority want "the comforts and conveniences of modern travel and living. It therefore seems undemocratic and unrealistic not to provide such housing or camping accommodations as most visitors desire." Even as thoughtful and committed a supporter of the national parks as Bernard DeVoto, writing in *Harper's* in 1953, expressed a view of park problems that indicates how far perceptions of the park purpose had strayed from its origin. Calling for increased appropriations to the National Park Service, he reports:

> A middle-aged couple with a Cadillac makes a formal protest: it is annoying that they must wait three-quarters of an hour to get a table at Lookout Point Lodge. . . . Another woman reports that the toilet at Inspiration Cliff Camp Ground has been clogged since early last evening. . . . A man pounds the desk and shouts that he hit a chuck-hole on Rimrock Drive and broke a spring.

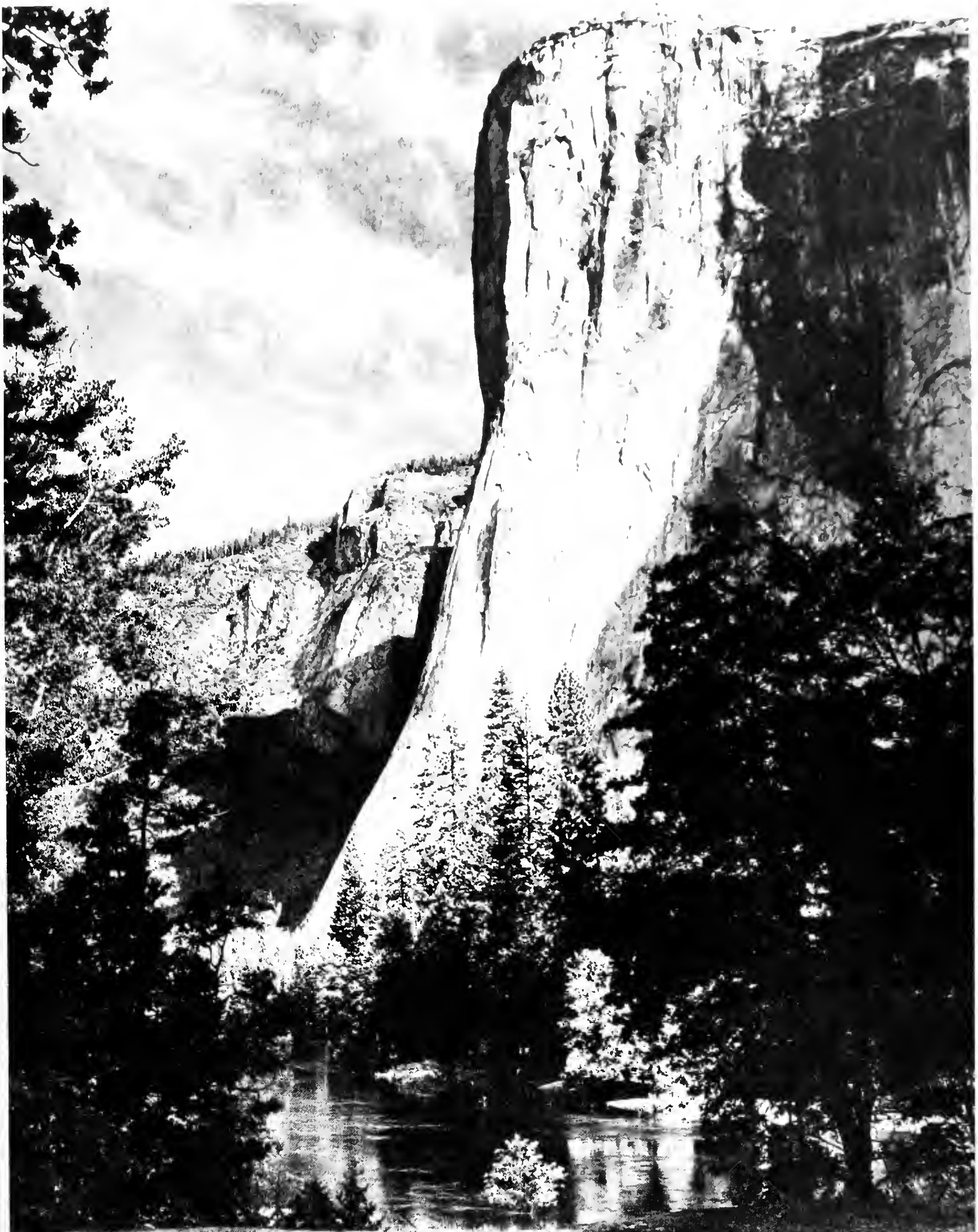
These are reasonable enough complaints, but they are essentially a list of grievances identical to those people have at home: potholes in the streets, inadequate plumbing, slow service. They are the urban complaints of urban denizens, produced by a park system that is providing an urban experience.

The greatest danger the parks face is the subversion of Olmsted's vision of democracy by the notion that the parks must serve the taste for convenience that cities have spawned. As recently as this year the National Park Service proposed a mechanical tramway to take visitors to the summit of Guadalupe Peak in Guadalupe Mountains National Park in Texas. The reason, it said, was that "all visitors should be offered the opportunity to reach such a strategic point, and by a mode of access convenient to . . . the majority." But what shall these visitors have reached when they attain the top of a mechanized mountain? Perhaps we can do no better than leave a final response to the always wise Aldo Leopold:

> Let me tell of a "wild" river bluff which until 1935 harbored a falcon's eyrie. Many visitors walked a quarter mile to the river bank to picnic and to watch the falcons. Comes now some alphabetic builder of "country parks" and dynamites a road to the river, all in the name of "recreational planning." The excuse is that the public formerly had no right of access, now it has such a right. Access to what? Not access to the falcons, for they are gone.

Tunnel through sequoia tree, ca. 1910

Bettmann Archive



El Capitan, Yosemite

Ansel Adams Magnum

Additional Reading

The following is not intended to be a comprehensive bibliography, but rather a descriptive listing, organized by subject matter, of the sources referred to or quoted by the author. For a month-by-month account of what is going on in the National Park Service (NPS)—and in the parks—see current issues of *National Parks & Conservation Magazine, Sierra Club Bulletin*, and *The Living Wilderness*.

Concessions in the National Parks

The current controversy between commercial concessionaires and the NPS is fully documented in the 515-page report of joint hearings held by the Committee on Government Operations and the Permanent Select Committee on Small Business, House of Representatives, 93rd Congress, 2nd Session, 1974. Entitled "National Park Service Policies Discourage Competition, Give Concessioners Too Great a Voice in Concessions Management," the report contains specific and strong recommendations for reforming the 1965 Concessions Policy Act, which governs practices of private concerns operating within NPS units. It can be found in libraries that serve as depositories of federal government documents or it can be obtained by writing to either committee. A summary of the report appeared in the May 1976 issue of *National Parks & Conservation Magazine* ("Congress Blasts NPS," pp. 25–26).

For a historical perspective on the development of this issue, write to the National Park Service, Washington, D.C. 20240, for a copy of "National Park Concessions," an archival document (1948) detailing the effects of the post-World War II "recreation boom" on NPS management policies. *Oh, Ranger!* a popular account of the NPS written in 1928 by Horace M. Albright and Frank J. Taylor and reprinted in 1972 (Old Greenwich: The Chatham Press, $3.95), includes discussions of very early problems with concessionaires (mostly railroads and hotels) bent on developing the resort possibilities of the first national parks.

The National Parks Idea

The philosophy of preserving selected aspects of the natural environment is discussed in Hans Huth's *Nature and the American: Three Centuries of Changing Attitudes* (Lincoln: University of Nebraska Press, 1972, $2.95) and Roderick Nash's *Wilderness and the American Mind* (rev. ed. New Haven: Yale University Press, 1973, $3.25). See, also, two other collections edited by Nash: *The American Environment: Readings in the History of Conservation* (Reading: Addison-Wesley Publishing, 1968) and *Environment and Americans: The Problem of Priorities* (New York: Holt, Rinehart and Winston, 1972), with articles by Hans Huth ("The Aesthetic Emphasis") and S.L. Flader ("Aldo Leopold and the Evolution of an Ecological Attitude"). George Perkins Marsh's classic treatise *Man and Nature* (1864), in which he propounds his ecosystematic view of humankind and discusses the setting aside of natural areas as a means of resource management, has recently been reprinted (Cambridge: Harvard University Press, $5.95). Aldo Leopold's *A Sand County Almanac* (New York: Oxford University Press, 1949, $1.95) is another environmental classic, with near poetic essays—"Conservation Esthetic," "Wildlife in American Culture"—imbued with the place of man in the ecosystem. Colin Fletcher's *The Man Who Walked Through Time* (New York: Random House, 1972, $1.95), a vivid account of a two-month hike through the Grand Canyon, explores man's relationship to nature in a national park, just as Olmsted and other early park planners intended the experience to be.

F. Fraser Darling and Noel D. Eichhorn's *Man and Nature in the National Parks* (write to Conservation Foundation, 1717 Massachusetts Ave. NW, Washington, D.C. 20036) is the result of a 1967 study commissioned to formulate ecologically sound management policies for the national parks. One may also write to the NPS for copies of its official policy statements. For insights into the NPS's response to the tremendous increase in park usage, compare the 1970 and 1975 management policies. A historical perspective on this developing problem may be gained by reading Bernard De Voto's "Let's Close the National Parks" (*Harper's*, October 1953, pp. 49–52); Steven V. Roberts's "Visitors Are Swamping the National Parks" (*New York Times*, September 1, 1969); and the March 1976 issue of *National Parks & Conservation Magazine* ("Guadalupe: Easy Access vs. Protection," p. 22). Write to the NPS for a copy of "The Workbook, Yosemite Master Plan, Guidelines for the Design of Alternatives," an experiment in eliciting public participation in the formulation of parks management policy.

History of the National Park Service

Robert Shankland's definitive, illustrated biography of the first director of the NPS, *Steve Mather of the National Parks* (rev. ed. New York: Alfred A. Knopf, 1971, $8.95), is an appropriate historical starting point. Mather's own work, *Progress in the Development of the National Parks* (Washington: U.S. Government Printing Office, 1916), should be available in many libraries. Ronald F. Lee's "Public Use of the National Park System: 1872–2000," prepared for the NPS in January 1968, is available by writing to them. Other standard references are John Ise's *Our National Park Policy: A Critical History* (Baltimore: Johns Hopkins Press, 1961); Jenks Cameron's 1972 monograph, *The National Park Service: Its History, Activities and Organization* (repr. New York: AMS Press, $15); and Paul H. Buck's *The Evolution of the National Park System of the United States* (Washington: U.S. Government Printing Office, 1946). An article by Donald C. Swain, "The Passage of the National Park Service Act of 1916" (*Wisconsin Magazine of History*, 1966, vol. 50, pp. 4–20), recounts the official congressional establishment of the NPS.

Three Early Parks

An account of the early development of Yosemite National Park is found in Carl Russell's *One Hundred Years in Yosemite: The Story of a Great Park and Its Friends* (rev. ed. Berkeley: University of California Press, 1947). Russell, an early park naturalist and, later, superintendent of Yosemite, also has an article in *Yosemite: Saga of a*

Century, 1864–1964, edited by Jack Gyer (Oakhurst: Sierra Star Press, 1964). Hans Huth's "Yosemite: The Story of an Idea," in the March 1948 issue of the *Sierra Club Bulletin* (pp. 47–78), tells of the evolution of NPS administrative philosophy in Yosemite. Edwin T. Brewster's *Life and Letters of Josiah Dwight Whitney* (Boston: Houghton Mifflin, 1909) is the biography of an early supporter of Yosemite and a prime mover in its establishment as the first national park.

Yellowstone's early developmental history was recorded in 1895 by Hiram M. Chittenden in *The Yellowstone National Park* (repr. Norman: University of Oklahoma Press, 1971, $1.95). H. Duane Hampton's *How the U.S. Cavalry Saved Our National Parks* (Bloomington: Indiana University Press, 1971) is a scholarly history of the management of our early national parks. Louis C. Cramton, a contemporary of Stephen Mather and a friend of the NPS in Congress, provided an insider's view in his *Early History of Yellowstone National Park and Its Relation to National Park Policies* (Washington: U.S. Government Printing Office, 1932). Aubrey L. Haines's *Yellowstone National Park: Its Exploration and Establishment* (Washington: U.S. Government Printing Office, 1974) is another well-illustrated historical treatment.

Primary sources on the early history of Niagara Falls as a natural park are more difficult to obtain. Two examples are Charles M. Dow's *The State Reservation at Niagara: A History* (Albany: J.B. Lyon, 1914) and J.B. Harrison's "The Movement for the Redemption of Niagara" (*New Princeton Review*, 1886, vol. 2, p. 233). Olmsted's ideas on the founding of a Niagara Falls park can be found in the "Special Report of the New York State Survey on the Preservation of the Scenery of Niagara Falls" (Albany: Charles Von Benthuysen & Sons, 1880) and the "Supplemental Report of the Commissioners of the State Reservation at Niagara, Report of Messrs. Olmsted and Vaux" (Albany: Argus, 1887).

Frederick Law Olmsted

Laura Wood Roper's *F.L.O.: A Biography of Frederick Law Olmsted* (Baltimore: The Johns Hopkins University Press, 1974, $15) is the only comprehensive account of the life and work of this outstanding figure in the history of the national park movement. This important book contains the account of Roper's discovery, in a nearly forgotten file, of Olmsted's long-neglected statement of early park philosophy—his 1865 Yosemite Report. This landmark document—"The Yosemite Valley and the Mariposa Big Trees"—was first published in the October 1952 issue of *Landscape Architecture*. For an explicit statement of his theory of city parks, see Olmsted's 1870 book, *Public Parks and the Enlargement of Towns* (repr. New York: Arno Press, 1970). Olmsted's professional papers, collected and edited in the 1920s by F.L. Olmsted, Jr., and Theodora Kimball, are now available in one volume: *Frederick Law Olmsted, Landscape Architect: 1822–1903* (New York: Benjamin Blom, 1969, $15.75). Albert Fein's analytical essay, *Frederick Law Olmsted and the American Environmental Tradition* (New York: George Braziller, 1972, $10), is but one of the many recent books about America's unsung hero of the natural beauty of the land.

John Muir

The Wilderness World of John Muir, edited by Edward Way Teale (repr. Boston: Houghton Mifflin, 1976, $4.95), provides a broad selection from Muir's writings; also recommended are two of Muir's books: *The Mountains of California* (1894) and *The Yosemite* (1912), both of which are available as inexpensive paperbacks (Garden City: Doubleday, 1961 and 1962). Robert Underwood Johnson, the editor of *Century* magazine who enthusiastically supported Muir and provided him with an effective publishing outlet, also provides us with fascinating insights into Muir's attitudes and activities in his own autobiography, *Remembered Yesterdays* (Boston: Little, Brown and Co., 1923). Holoway Jones's *John Muir and the Sierra Club: The Battle for Yosemite* (San Francisco: Sierra Club Books, 1964, $10) is perhaps the best book available on Muir as a political activist.

An ardent admirer of our national parks, **Joseph L. Sax** spends much of his spare time hiking their trails. For the past ten years he has studied park history, use, and administration from his base at the University of Michigan Law School where he teaches environmental law (*see* "Environmental Action: A Passing Fad?" *Natural History,* June-July 1976). That decade of research has led Sax to the conclusion that the statutes governing the use of public lands are among the least understood and least satisfactorily executed of any United States laws relating to natural resources. Sax drew up the model for legislation that was eventually enacted in 1970 as the Michigan Environmental Protection Act, and wrote a book, *Defending the Environment,* that spells out how citizens can use the courts to combat environmental degradation. His active participation in a number of national and international groups dealing with environmental laws led to an award in 1975 from the U.S. Environmental Protection Agency.

Yosemite Falls, 1879 New York Public Library

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The Perils of Primates

by Jaclyn H. Wolfheim

An animal's body size and range are key factors in its survival

As the number of endangered and extinct species continues to grow, an awareness of the threats to wildlife is radiating out from traditional conservation circles and into the larger public forum. But despite all the publicity attendant on the release of endangered-animal lists, the interaction of the factors contributing to the decline of a species has not received widespread attention.

The primates are a good case in point. Although authorities differ on the exact number, there are about 149 species of primates: 33 prosimians, 16 marmosets and tamarins, 25 New World monkeys, 65 Old World monkeys, and 10 apes. Several of these species, such as the golden-lion tamarin and the orangutan, are widely recognized as being endangered, but a few are considered abundant or pestiferous. The reasons why one species of primate is threatened with extinction while another is not apply to virtually all animals, and these reasons must be understood before any sensible action can be taken to prevent a species from disappearing.

The survival status of any animal is determined by the interaction of ultimate and proximate factors. Ultimate factors are those determined by the genetic information and evolutionary history of the species. Included in this group are original geographic range, body size, habitat requirements, population density limits, and behavioral traits. These factors are species specific. They constitute the foundation which has to absorb the impact of proximate factors (habitat destruction and hunting).

The most important ultimate component of a species' status is the size of its geographic range. The result of geologic events, climatic changes, and migrations, geographic range size is generally delimited by natural barriers, such as bodies of water, mountain ranges, or climatic and vegetation zones, which the animals cannot cross. Among the primates, some species have relatively restricted ranges, for example, the gelada baboon with a range size of about 75,000 square miles. Others, however, occupy extensive ranges; the olive baboon, for instance, is found throughout an area of more than two million square miles.

At least 62 species of primates inhabit ranges of less than 100,000 square miles (smaller than the state of Oregon). Another 37 species occupy ranges of 100,000 to 300,000 square miles (smaller than the state of Texas). There are also many subspecies, for example, of red colobus monkeys, guerezas, and lar gibbons, that occur only within extremely small areas.

Mountain Gorilla—*Endangered*
Body size: Large
Geographic range: Limited
Habitat: Specialized (montane forest)
Habitat alteration: Severe (logging, livestock grazing)
Home range: Large
Hunting: Meat, sport
Reproduction: Slow

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Spider Monkey *(above)—*
Moderately threatened
Body size: Medium
Geographic range: Large
Habitat: General (forest)
Habitat alteration: Severe (logging, agricultural clearing)
Home Range: ?
Hunting: Meat; collection for biomedical research

Orangutan *(right)—Endangered*
Body size: Large
Geographic range: Limited
Habitat: General (forest)
Habitat alteration: Severe (logging, agricultural clearing)
Home range: ?
Hunting: Meat; collection of young for zoos
Reproduction: Slow

Although wide-ranging species may be severely threatened by other factors, all species with small geographic ranges are more vulnerable than similar wide-ranging forms. Habitat alteration or hunting pressure, which would have an insignificant effect on a widely distributed animal, may eliminate a species that is found only within a small area.

Body size is the second most important ultimate factor influencing the status of primate populations. Among the primates, body weight ranges from two or three ounces (mouse lemur, pygmy marmoset) to more than 300 pounds (gorilla). And within each primate family, certain species may be many times the size of others: mandrills are ten times the size of talapoin monkeys; howler monkeys are roughly ten times the weight of squirrel monkeys.

In general, larger animals need more food and larger feeding areas than similar smaller animals. This makes them more vulnerable to habitat disturbance. Larger mammals also mature and reproduce more slowly than most small species; hence they

M P L Fogden, Bruce Coleman, Inc

are slower to replace lost members of their population. The large primates are easier to hunt and are shot in preference to small ones because their carcasses provide more meat.

Each species of primate has its own habitat requirements, including composition and structure of the vegetation it can utilize and the temperature, humidity, and altitude at which it can survive. Species with specialized habitats are more vulnerable than generalized forms. Specialists are usually able to survive only within narrow limits of environmental conditions. Even a slight perturbation in the ecosystem may be sufficient to disrupt the adaptive strategy of a specialized species and decrease its chances for survival. More than 70 percent of all primate species are restricted to forest habitats. Many of these species can occupy only certain kinds of forests—mangrove forest (proboscis monkey), high-altitude evergreen forest (Nilgiri langur), or coastal, gallery, or swamp forest (collared mangabey).

The population density of a primate species is influenced by its social organization, group size, intergroup spacing, home-range area, and distribution of resources—primarily food, water, sleeping sites, and cover. Above certain levels, density-regulating mechanisms will prevent further population growth; below certain limits, extinction will become inevitable.

Some species of primates normally exist at low population densities. Typical gorilla populations average one to six animals per square mile. Other species regularly achieve high densities: 100 to 200 mantled howler

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Red Uakari *(above)—Severely threatened?*
Body size: Medium
Geographic range: Limited
Habitat: ?
Habitat Alteration: ?
Home Range: ?
Hunting: Meat

Lar Gibbon (white-handed)—*Moderately threatened*
Body size: Medium
Geographic range: Moderate
Habitat: General (forest)
Habitat alteration: Severe (logging, agricultural clearing)
Home range: Small to moderate
Hunting: Meat; collection for pet trade

monkeys may be found per square mile of suitable habitat. Certain species live in small groups, consisting of one or two adults and their offspring (angwantibo, night monkey). Some primate species are commonly found in large groups, numbering more than fifty individuals (talapoin monkeys, olive baboons). Among mobile species, groups may occupy home ranges of more than twenty square miles (patas monkeys, rhesus macaques). Groups of sedentary species may stay within home ranges of less than 0.5 square miles (red colo-

bus monkeys, red howler monkeys).

In general, if all other factors are constant, species with low population densities, small group sizes, or large home ranges should be more vulnerable than species that can exist at high densities, in large groups, or in small home ranges. For most species of primates, we do not have the critical data regarding typical population densities, group sizes, or home-range areas. But two examples from among the apes illustrate the importance of demography in determining the survival potential of a species.

Orangutans wander over long distances and are normally solitary, the mother and her young offspring forming the only consistent group. Deforestation can severely affect populations by preventing long-range movements because the animals will not cross cut-over areas. When populations are concentrated in remaining patches at unnaturally high densities, reproduction may be adversely affected.

Gibbons live in small family groups consisting of one mated pair and their immature offspring. These groups defend nonoverlapping territories with vocal displays against other groups of the same species. Thus a large area is needed to support a population of gibbons.

Certain behavioral traits may affect a species' ability to withstand pressures of habitat alteration or hunting. For example, an animal that does not cross open ground (blue monkey) is more vulnerable to deforestation than one that will travel across treeless areas to reach or leave isolated patches of trees (olive baboon). Species that have effective predator

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avoidance strategies, such as wariness, lookouts, defense reactions, or the ability to learn to avoid human beings (guenons, macaques, and baboons), are more difficult to hunt than less responsive species, such as red colobus or howler monkeys. These behavioral traits, with the other ultimate factors, are the determinants of which species will be threatened with extinction. But they do not directly cause the decline of populations.

Proximate factors are those immediately responsible for the decline, expansion, isolation, or merging of populations. Naturally occurring events, such as changes of climate, topography, soil, or riverbeds, can cause changes in the status of populations. But today, human activities are overshadowing, exaggerating, and hastening natural processes. Thus the most important proximate factors affecting primate populations are human enterprises. These may be broadly classified as habitat alteration, such as deforestation, agricultural expansion, and grazing; and human predation, such as hunting, killing for crop protection, and collection of live animals.

Habitat alteration is the most serious threat to primate populations. Most commonly it begins with the cutting of trees. Nearly all species of primates require trees in their habitats, and some require trees of particular species or shapes. Any removal, reduction, or change in the composition of trees in an area will affect resident primates. Most wild primates cannot survive at normal densities in areas largely denuded of trees; most cannot live in monocultural commercial forests or plantations of exotic crop trees.

Every forest-dwelling primate for which sufficient population information is available (about 98 species) can be shown to be declining due to disturbance of its habitat. In some countries, extensive deforestation is achieved by clear-cutting: the removal of all timber from an area. On productive soils, forests are replaced with farms. Peninsular Malaysia, Sumatra, and coastal Cameroon are examples of regions in which large expanses of primate habitat have been deforested for agricultural use.

In many areas of the tropics, shifting cultivation is practiced. Patches of forest are cleared, cultivated for one or more seasons, and then left fallow for several years while nearby patches are cleared and cultivated. The impact of shifting cultivation can be significant. In the Ivory Coast, 30 percent (2,800,000 hectares) of all forested land was cleared in this way between 1956 and 1966. In some areas, secondary succession quickly recolonizes abandoned fields adjacent to forests. The resultant thick, brushy vegetation provides favorable habitats for some primates, such as gorillas, talapoin monkeys, and cotton-topped tamarins. These species may actually benefit from limited rotational agriculture in which patches of forest are left intact.

Abandoned fields that are far from forests, of poor soil, or that have been overexploited or exposed to heavy rains and direct sunlight are not reinvaded by trees. Leaching and erosion make such fields unsuitable for forest plants, and they are thereafter unavailable as primate habitats. This process is occurring over large areas of the tropical forest zone.

Selective logging, especially where only a few trees per acre are removed, is generally less harmful to primate populations than clear-cutting. Certain species, such as long-tailed macaques, maroon leaf monkeys, and guerezas, can tolerate selective logging and may even benefit from the increased undergrowth promoted by limited removal of canopy trees. Many species, however, can survive only in undisturbed, mature primary forest and are eliminated even by selective logging. These include Diana monkeys, gray-cheeked mangabeys, and Kloss' gibbons. Over-all, the number of species whose available habitat is being decreased and whose populations are declining due to the cutting of forests far outweighs the few that may benefit from limited logging.

Arboricides are sometimes applied to selectively logged forests and commercial tree farms in order to hasten regeneration of commercially valuable species by eliminating "undesirable" plants. But these undesirables often provide major food sources for resident primate populations. Thus arboricide use tends to reduce the carrying capacity of primate habitats. This practice has been implicated in the decline of primate populations in Uganda and Japan.

Another major cause of deforestation is warfare. Bombing and the use of military herbicides have deforested large areas of Vietnam, Laos, and Cambodia. No direct evidence is available, but it is highly likely that the habitats of twelve species of primates, including the little-known douc langur, Tonkin snub-nosed monkey, Francois' leaf monkey, pileated gibbon, and lesser slow loris, have been severely damaged.

Reforestation with rapidly growing exotics such as eucalyptus, cedar, and pine has been practiced extensively in South America, Africa, and Asia. Most primates cannot survive in these forests. Blue monkeys, rhesus monkeys, and Japanese macaques are three primates whose decline is blamed, in part, on the introduction and spread of exotic trees.

Certain types of moist forest, such as gallery, swamp, or mangrove forest, are dependent upon the supply and distribution of surface water. These habitats can be destroyed by water-control projects—dams, diversion of rivers, and swamp drainage. When this occurs, primate species that are specially adapted to these moist forests cannot survive. Such species include the red colobus monkey, DeBrazza's monkey, talapoin monkey, and proboscis monkey.

Although forest-dwelling primates have been the ones most severely affected by habitat changes, primates living in woodland, savanna, grassland, and scrub have also been influenced by habitat alteration. Most of these species need some trees for protective cover and sleeping sites. Their refuges, primarily riverine woodland and scattered trees in savanna, have been cut extensively for

Long-tailed Macaque—*Abundant*
Body size: Medium
Geographic range: Large
Habitat: General (mixed forest; open areas; edges)
Habitat alteration: Minor (logging)
Home range: ?
Hunting: Meat; collection for biomedical research

M.P. Kahl; Bruce Coleman, Inc.

fuel and lumber. Even such abundant and adaptable forms as olive baboons and rhesus macaques are declining because of the cutting of trees.

Woodland, savanna, and grassland are also being converted to cultivated fields or used as pastures. Primates may thrive by eating cultivated foods but only if natural vegetation remains nearby for refuge and if farmers are tolerant. Livestock may denude the soil of vegetation by trampling and compete with native primates for scarce water supplies, thus exacerbating the effects of drought, as in sub-Saharan Africa and India. In a few cases, the addition of artificial water sources may improve arid habitats for such primates as chacma baboons and patas monkeys, which drink from cattle troughs and irrigation ditches. In general, however, human activities reduce the ability of nonforest habitats to support primates.

The destruction of habitat overshadows all other proximate factors that influence the survival of primate populations. No degree of adaptability or regulation of trade in animals can save a species if all of its habitat has been bombed with napalm, razed by bulldozers, or planted in soybeans. Conversely, it is difficult to hunt a species to extinction if its original habitat is left intact.

All of the other proximate factors that adversely affect primate populations are forms of human predation. Primates are killed or captured to prevent them from damaging crops or property, to obtain their meat and pelts, or to sell them alive to others who wish to use them.

Some species of primates are considered to be damaging to agriculture and are subject to extermination drives by shooting, trapping, or poisoning. These include most of the baboons and macaques, vervets, redtail monkeys, white-collared mangabeys, patas monkeys, white-fronted capuchins, and chimpanzees. Chacma baboons are sometimes shot because they kill lambs and vandalize automobiles and campsites. Blue monkeys are harassed where they damage exotic tree plantations.

Most primates that are considered to be crop pests are not persecuted severely. Thus this factor alone would not be expected to seriously alter the status of a primate population. However, if the species has a small geographic range or is already being affected by habitat alteration, as is the case with the pig-tailed macaque and the white-colored mangabey, crop protection can have a serious effect upon populations.

Because domestic livestock do not thrive in many regions where primates are found, sources of animal protein are scarce and often limited to wild game. Traditional hunting with primitive weapons and traps, as well as with modern firearms, persists even in areas where other protein sources have been introduced. Primate meat is considered a delicacy in many regions and is often highly valued.

Hunting can severely deplete populations of primates with large body size and slow recruitment rates, small geographic ranges, or disturbed habitats. Species experiencing heavy hunting pressure include drills, mandrills, chimpanzees, mantled howler monkeys, and Humboldt's woolly monkeys.

In parts of Asia and Africa, religious or traditional precepts forbid the killing or eating of certain primates. These taboos have protected several species from hunting pressure, such as rhesus macaques, gray langurs, chimpanzees, and lar gibbons. Today, however, in the face of increasing food shortages, reverence for these species and tolerance for their crop destruction are decreasing and traditional protection is waning.

Certain species are hunted not solely for their meat but for special coveted attributes. Guerezas are killed in large numbers for their skins, which are made into rugs and wall hangings. Nilgiri langurs are hunted for their flesh, glands, and blood, all of which are valued for their presumed medicinal and rejuvenatory powers. Some species, such as gorillas, are considered challenging prey and so are hunted for sport.

Another major type of predation by humans is the collection of live animals for sale, primarily to users in industrialized, temperate countries. Live primates are collected for use as subjects in biomedical research and drug testing, as pets and entertainers, and as exhibits in zoological gardens. The losses sustained by natural populations due to collection are often much greater than the number actually received by these institutions. High postcapture mortality and wasteful capture methods—such as the killing of adult females in order to obtain their young—can result in from four to six or more deaths for each animal imported. Collection can exert significant pressure on a species with a small geographic range, large body size, or disturbed habitat.

According to a recent survey by the Institute for Laboratory Animal Research, biomedical research and the pharmaceutical industry in the United States in 1973 utilized primarily rhesus macaques (about 20,000), vervets, owl monkeys, and squirrel monkeys (more than 2,000 of each), and long-tailed macaques and moustached tamarins (more than 1,000 of each).

The pet industry does not consume as many primates as do research programs and drug production, but several species have been affected, some heavily, by the pet trade. In the United States, New World monkeys are sold as pets more frequently than other primates. Species that have been imported for the pet trade in large numbers include spider monkeys, tufted capuchins, white-fronted capuchins, Humboldt's woolly monkeys, squirrel monkeys, Goeldi's monkeys, common marmosets, pygmy marmosets, and cotton-topped tamarins. In general, primates make poor household pets. They carry diseases, are often morose or short-lived in captivity, and may become unruly or dangerous as adults.

Zoological gardens are another major recipient of imported primates in the United States. Almost every species of primate is represented in at least one American zoo, and many popular forms are present in nearly every zoo. For example, more than 100 individuals each of gorillas, chimpanzees, and orangutans were on exhibit in thirty-six major American zoos in 1972. More than 50 individuals of such rare species as drills and lion-tailed macaques were also on display. In general, birth and survival rates of primates in zoos are suspected to be low and death rates high in relation to the number of animals received. To maintain a stable population, zoos must continually import more individuals from the wild.

Some zoo advocates contend that zoos can save endangered species by breeding them in captivity and reintroducing them into suitable habitats. This procedure seems to have a low probability of success for most species of primates. First, it has been difficult to breed endangered primates. Most of them are specialized species and usually do not reproduce well in captivity. Breeding success has been achieved with some endangered species, but in many cases animals born in captivity have not bred; thus collection of wild animals must continue to supply breeders. Second, the premise that captive-bred primates can be reintroduced into their native habitats has not been tested. Since many primate behavior patterns are learned through experience, it is probable that many captive-reared animals could not survive in their natural habitats. Attempts to rehabilitate confiscated pet orangutans have not only met with a high rate of failure but also entail the risk of introducing human diseases into wild orangutan populations.

If any suitable habitat remains for a species, it would be safer to leave the animals in the wild on the chance that they might survive rather than to deplete the population for a captive-breeding program. Captive breeding in zoos and laboratories is necessary to provide primates for exhibit and research. It can help to conserve a species by preventing the collection of wild animals. But it probably cannot save a primate species on the brink of extinction.

Over-all, 54 species (36 percent of the 149 species of living primates) are severely threatened. The apes, African and Asian leaf-eating monkeys, Madagascan prosimians, and other island species have the highest representation in this category. Twenty-seven species (19 percent) are moderately threatened. Several of these—the chimpanzee, spider monkey, and red colobus monkey—are severely threatened in parts of their range.

Altogether, 81 species (54 percent of all primates) are severely or moderately threatened and in need of immediate protection. As field research continues, more species will probably be found to be threatened to some degree.

Such a high proportion of primate species are threatened with extinction because, in general, they are subject to a number of ultimate factors that increase their vulnerability. Many primates are large animals, at least as compared to other arboreal animals such as birds or squirrels. Most reproduce slowly; hence their populations cannot withstand heavy mortality or adapt rapidly to changing conditions. They are also relatively specialized to forest conditions. These inherent traits—combined with the proximate factors of widespread destruction of tropical forests, hunting, and collection of wild stocks—represent a composite picture of primate vulnerability to extinction.

No action to protect primates can have much effect on the ultimate factors influencing population status. These factors change only through the slow process of evolution and are usually not affected by man's activities. Most biologists do not favor the translocation of populations or the introduction of artificial food sources to increase the carrying capacity of habitats because such attempts to alter natural communities are potentially dangerous. Any disturbance of a natural ecosystem is likely to upset balanced components and lead to unexpected disasters. Although no actions to change ultimate factors are recommended, further research into the ecology of primate populations would greatly facilitate conservation decisions.

Most of the proximate factors threatening primate populations are directly caused by human activities and so are subject to modification. Protection of remaining nonhuman primate populations would require some major changes in economic practices on a worldwide scale. Clear-cutting of tropical forests would have to be eliminated, with low intensity, selective logging permitted only in certain areas. Commercial foresters would be required to replant with assorted native tree species and to discontinue the use of herbicides. The market demand in affluent countries for hardwoods and products (such as coffee, tea, bananas, and rubber) grown in tropical forest areas would have to decrease.

Another helpful development would be recognition of the value of native vegetation for watershed protection, soil conservation, and wildlife reserves. Governments would encourage the preservation of natural areas by economic rewards to landowners who leave areas undeveloped. Responsible authorities would also institute educational and medical programs and economic incentives to promote family-size limitation, slowing rates of population growth and decreasing the pressures for agricultural expansion. These programs, coordinated with the introduction of alternate protein sources and methods of utilizing them, would reduce hunting pressure on primates and other wildlife.

As part of this Panglossian world, biomedical researchers, pharmaceutical companies, pet dealers, and zoos would refuse to purchase any threatened species, large numbers of any species, and any primate that may have been captured by killing the mother (any dependent infant). All users of primates would substitute local or domestic animals wherever possible and establish self-sustaining breeding colonies to provide animals for their own use.

The prospects for achieving even a portion of this ideal world are not bright, but a few recent developments are encouraging. In October 1975, the U.S. Department of Health, Education, and Welfare restricted the importation of primates to institutions needing the animals for scientific, educational, and exhibitional use only. This virtually eliminates the United States pet trade and enables stricter regulation of the importation of primates. In April 1976 the Department of the Interior proposed the addition of twenty-seven primates to its list of endangered and threatened species. If approved, this would bring the total number of primates covered by the U.S. Endangered Species Act to sixty-two.

The current, most crucial arenas in the struggle for primate conservation are in the attainment of reserves, changes in forest management practices, and decreases in the rate of agricultural expansion. Created and potentially controllable by man, these proximate factors—so influential to the survival of remaining primate populations—must be acted upon soon. Time is running out for most primates. □

Life at the Cloud Line

by William G. Wellington

Along the sharp weather gradients of mountains, plants and insects adapt to a precarious existence

The air is restless over mountains. Within loose constraints imposed by the time of day, the season, and the type of regional weather, the local air currents swirl in patterns set by the salient features of the terrain. Clouds grow where currents rise and dissolve where the air descends again. These clearing and clouding patches of sky mark places where the influence of the surrounding topography often equals, and sometimes exceeds, the effects of regional weather systems on local temperatures and precipitation.

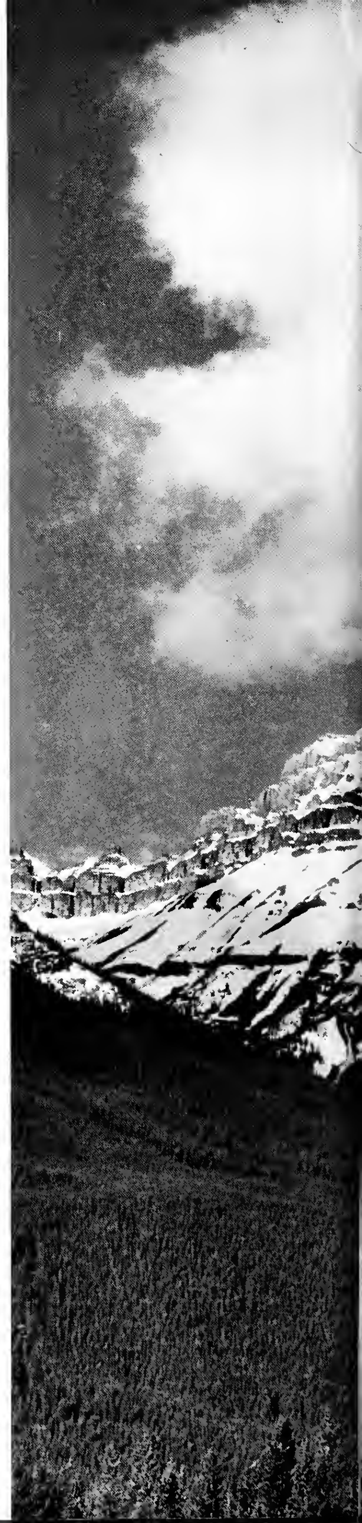
Mountains also compress into a few thousand vertical feet several bioclimatic zones, which in flatter country stretch poleward for hundreds or even thousands of horizontal miles. By exploiting the combination of bioclimatic compression and topographic influences that mountains offer, a researcher can find an area small enough to be quickly covered, but so topographically diverse that it may simultaneously offer two different kinds of weather in adjoining places. While the sun shines in one spot, rain may fall nearby. That kind of outdoor laboratory has much to offer a biometeorologist who wishes to observe free-living populations in their own habitat, which is why I often choose the high country to study the effects of weather on insect behavior and survival.

The rugged terrain of the Canadian Rocky Mountains affects all levels of the meteorological hierarchy, from the microscale of the leaf and twig climates where insects dwell, to the subcontinental scale of the great weather systems that sweep through the North Temperate Zone. The speed and direction of these huge traveling storms, with their attendant warm and cold fronts, are scarcely affected by ordinary features of the underlying terrain. But the high spine of the Rockies hinders all those weather systems that enter the continent from the North Pacific or Alaska. Weaker systems may be so disrupted that only their higher cloud layers survive to cross the main ridges. Even the active systems that eventually reach the Bow and Athabasca valleys in Alberta must first enter those valleys through the passes that breach their western walls. As they invade those passes and valleys, the various kinds of frontal systems behave differently, with inevitably different biological results.

When a Pacific or Alaskan cold front blusters into the Bow Valley, it unceremoniously shoulders aside all the old air lying there, scouring it out from ridgetop to valley bottom. In comparison, a Pacific warm front seems self-effacing. Unlike the cold front's towering storm clouds, the tattered forerunners of the warm front discreetly bob along the top of the layer of old air filling the valley. Even a day or so after frontal passage, most of that old air may still lie in the valley bottom, mixing only slowly with the new layer of milder air above it.

The depth of the old air varies, depending on the size and shape of a valley and its connecting passes. Within one season in a particular valley, however, the depth changes little from front to front. The most obvious difference occurs between summer and winter, when the temperature and density differences between existing and incoming air masses are greatest.

The boundary between the new and old air masses is better defined in narrow, steep-sided valleys, such as the Bow, than in very broad valleys, such



A cloud forms over Mount Pilot in the Canadian Rockies. Clouds from such mountains drift away in lines and drop bands of rain on adjacent valleys.

as the Athabasca. In a narrow valley, the location of the air mass boundary is revealed by wisps and thin rolls of clouds that linger on the slopes as the postfrontal cloud deck thins and begins to lift above them. This phenomenon is not so apparent in a broad valley, where the steplike series of benches rising from the river tends to block the view of the middle slopes. But there is a biological indicator that can be used to locate the boundary in either type of valley. "Red belt," the winter damage to the foliage of lodgepole pine that occasionally appears in the eastern Rockies, is a product of the air mass interface.

Many suburban gardeners have found that their prized ornamental pines can withstand prolonged cold better than alternating thaws and freezes. During the spring following a midwinter thaw, the needles of the affected trees suddenly turn reddish brown, revealing hitherto unsuspected winter killing. The pines crowding the slopes of the Bow and Athabasca drainages are not exempt from comparable winter damage. After winters in which the valleys are alternately invaded by mild Pacific and frigid Arctic air, large numbers of pines redden. The damage is less noticeable after mild winters and even rarer after very cold winters.

The extent of red belt varies with local topography, but the name comes from the narrow reddish bands that suddenly appear on the steep flanks of the narrowest valleys in springtime. On very steep slopes, there may be only two or three trees between the top and bottom of a band, so not many trees are affected, even where the bands are several miles long. Often, the bands are not noticeably deeper in wider valleys, but since many more trees crowd the gentler slopes of a broad valley, there may be thousands, instead of hun-

William G Wellington

After a warm front has passed, wisps of clouds continue to linger at the top of a residual layer of cold air in the Bow Valley.


William G. Wellington

dreds, killed or damaged there, even when the bands are no thicker than in the narrow valleys.

The bands occur near the top of a valley's winter air pool. Red belt seems to be produced in the boundary layer that separates each incoming warm air mass from the residue of the last cold invasion. Even in summer, the association of the damage with the air mass boundary is easy to see. Whenever a Pacific warm front overruns a residual layer of cool air, scud rolls, which hug the slopes after frontal passage, always form near the marks of the previous winter's red belt.

The physiological basis of the damage has not been established. Perhaps the pine needles die because the warm chinook winds from the Pacific remove too much moisture from the exposed crown while the roots, inactive in the still frozen ground, remain incapable of replenishing the foliage's water supply. Alternatively, even brief exposure to higher temperatures may make the foliage more vulnerable to freezing if the cold air suddenly returns. Whichever is involved, the close association of the injury with the boundary layer deeply implicates the rapidly alternating winter temperatures occurring there during successive onslaughts of warm Pacific and frigid Arctic air.

Following the most serious episodes of red belt, other kinds of vegetation replace killed pines, and the habitats of insects and other animals living in the air mass boundary zone begin to change. But far more sudden and drastic changes in habitats can be produced by the same air mass interactions that lead to red belt. Many of the late winter rockslides and avalanches that strike high mountain valleys are caused by the sudden rain or rapid thawing brought by the warm air to the slopes above the boundary layer. The resultant shifts in the rocks or snowpack spell disaster for the overwintering plants and animals below, as the slides destroy every habitat they traverse.

A variant of that winter havoc is occasionally unleashed farther west, when warm Pacific air overruns a shallow layer of Arctic air in the coastal valley and canyon of the Fraser River in southwestern British Columbia. When rain from the warm air falls through the shallow Arctic air in the valley, it freezes on every surface. During such "silver thaws," the weight of the accumulated ice brings down roofs, trees, and power lines. In the canyon the warm air bathes the snow-covered slopes above the cold layer, causing avalanches severe enough to block the roads and railways that cling to the canyon walls below. On such occasions, when the existence of every lifeline on which coastal city dwellers depend for food and warmth is threatened, we are forcibly reminded how vulnerable animal populations are to montane winters.

Animals need not lose their food or shelter in avalanches or silver thaws to lose their lives. The lethal threat can be more direct. The caterpillars of the lodgepole needle miner, for example, overwintering inside the needles of the Bow and Athabasca pine trees, are even more susceptible than their hosts to the severity of mountain winters.

When many fronts pass during the winter, the valleys are blanketed by frontal and postfrontal clouds most of the time. Since these clouds reduce outgoing radiation, there is no drastic radiant cooling to create massive inversions of air temperature at valley bottom. Instead, air temperature usually decreases normally with height. Ambient temperatures for the pine needles and their small inhabitants therefore are usually no harsher near the valley floor than they are on the upper slopes.

The overwintering caterpillars of the needle miner die when the temperatures of the pine needles hover near -30°F for much more than a day. In winters when many fronts pass, such very cold periods are usually brief. In addition, the fresh snow that covers the pine boughs after each storm insulates the dormant insects from the harsh surrounding temperatures. Consequently, not many die of cold anywhere in the valley, although a few more may succumb on the higher slopes than on the lower ones.

In contrast, during winters in which Arctic air is dominant, a great cell of high pressure may stagnate over the region for weeks after the passage of a cold front. Steady radiant cooling through virtually cloudless skies creates temperature inversions that can chill the valley bottom 30 to 40 degrees below the temperature of the middle slopes, where the top of the inversion lies. (Above that

level, temperatures again fall off normally with height.) In such cold weather, even the "high" temperature at the top of the inversion is several degrees below freezing. The temperatures at the bottom of the inversion and on the slopes above it thus fall far below the needle miner's lethal temperature while the inversion lasts. During such winters, all of the insects in the valley bottom and most of those on the higher slopes die. Consequently, the hibernating insects on the middle slopes are the only ones that survive to repopulate the valley pine stands.

The peculiarities of mountain weather have placed the lodgepole needle miner in a curious situation. Although in summer the insect may deposit more eggs and develop faster at low elevations, where it is not so affected by the winds and rain-soaked foliage found more frequently upslope, it often suffers its greatest winter mortality in the lowest places. But even though its overwintering survival is occasionally better on the upper slopes than in the valley bottom, its moths rarely lay enough eggs at high elevations to produce a significant population.

The middle slopes therefore provide a refuge in which the insect is most likely to survive the worst weather and from which it can later repopulate less tolerable places. The continuing existence of the insect in the Canadian parks thus is dependent on the midslope refuges, although neither egg laying nor rate of development are as good in the refuge zone as they are in the other habitats.

Like the lodgepole needle miner, the black pine-leaf scale also suffers drastically from the effects of air masses interacting in narrow valleys. This insect lives on the needles of several kinds of pines in western North America, where its more northern populations are often decimated by winter cold. In northeastern Washington virtually all of the scale insects near valley bottom are killed when prolonged inversions of temperature develop in Arctic air. Like the needle miners, the scales higher on the slopes survive because they live near the top of the inversion. In Washington, however, drainage of cold air from one valley into another sometimes rearranges that vertical distribution of mortality.

The worst mortality among the scale insects at valley bottom occurs when they are suddenly subjected to an autumn invasion of Arctic air before they have become acclimated to low temperatures. In some low-lying valleys, however, the insects in the valley bottom are subjected to recurrent drainage of cool, but not lethally cold, air from higher, adjoining valleys earlier in the fall. The ability of these insects to withstand very cold air improves after each such exposure. Throughout the autumn, therefore, they are slowly acclimated to lower and lower temperatures and thus become more resistant to cold than insects living higher on the slopes. Once that conditioning process is complete, a sudden influx of very cold air has much less effect on the winter-hardy scales at low elevations than it has on those higher upslope. In one recorded episode, virtually all the scales at higher elevations were killed, whereas only 40 percent died at the lower levels—a dramatic reversal of the usual pattern of winter mortality.

Such insects as the pine-leaf scale and the lodgepole needle miner go through sessile stages during which they are attached to plants. Once settled on their hosts, these insects cannot evade the weather; they can only endure or perish. How effectively their motile stages disperse to new localities is, therefore, vitally important to their persistence in a region. We have already seen that needle miner moths, like other winged insects, successfully disperse and lay eggs in new localities only when ambient temperatures and moisture levels permit. But the scale insects and their sessile kin (the woolly aphids, for example) do not produce winged females. Their major dispersal takes place when the tiny hatchlings drift away on air currents.

Common sense suggests that dispersal by drifting must have evolved in a setting where hosts were plentiful and uniformly distributed. Otherwise, prohibitively high losses among the vulnerable flotsam would have soon disposed of the habit and its unsuccessful practitioners. But that brand of common sense may be more relevant for would-be aeronauts in level terrain. Different rules apply in the mountains. The progenitors of sessile montane insects must have had a special opportunity that is still open to their descendants—the chance to become effective, though unwitting, exploiters of the cross-valley transport system that is part of the daily circulation pattern in high valleys.

In many valleys one side is warmed by the morning sun while the other side is still shaded. The most familiar products of this unequal heating are the clouds that soon appear over the sunlit side of the valley. Less familiar, because it is invisible, is the bulk of the cloud-forming mechanism, the cross-valley circulation.

As the warmed air begins to rise up the sunlit side of the valley, it is replaced by air from the valley floor and the opposite shaded slopes. Unless clouds from an incoming front appear early enough in the day to disrupt the process, a return crossflow develops above the ridges to compensate for that near the valley floor, and the whole circulation strengthens as the sun's warmth increases.

Cross-valley circulation may be disrupted at midday if both sides of the valley are sunlit then. Whether a reversed circulation develops thereafter depends on the size and location of the clouds that formed during the morning. If very large cloud shadows still cover most of the west-facing slopes after midday, there will be in-

sufficient surface heating for a reverse flow to develop, so a different circulation pattern will evolve over the valley as the afternoon sun wanes.

While the earlier cross-valley circulation persists, however, it can transport tiny aeronauts from their original bioclimatic zone on one side of the valley to the comparable zone on the other side. Thanks to the stratified vegetation on mountain slopes, that cross-valley transport system makes drifting in montane environments a more predictable enterprise than a casual observer would expect. Although such dispersal can become hazardous if frontal weather alters the circulation while many insects are airborne, it remains profitable for species that are sufficiently fecund to absorb these occasional losses.

Because of these losses, however, even highly fecund species are rarely destructive in their native habitat. If, however, they are introduced into less rugged terrain that also supports a uniformly distributed food supply, their dispersal area suddenly becomes much larger and far less channeled. If other aspects of their new environment are equally favorable, their numbers will inevitably increase. In extreme situations, such insects can become unbridled pests in their new habitat.

The balsam woolly aphid achieved just that status when it was introduced into North American forests. Undoubtedly, several aspects of its new environment, including some possibly less resistant hosts, contributed to its increased stature as a pest on this continent. But its prior adaptation to cross-valley transport, which has scarcely been considered, must also have played a major role.

In European mountains where the woolly aphid still persists, the intermittent hazards and recurring benefits of cross-valley transport would inevitably have affected its coevolution with its original hosts. Although it must have been an occasionally serious pest on those hosts, it clearly was not an overwhelming one. On the gentler, fir-carpeted hills and plateaus of our northeastern region, the balsam woolly aphid was freed from its circumscribed cross-valley transport system. The larger circulation patterns of the great North America weather systems gave it infinitely wider access to a larger supply of susceptible hosts.

Increased food supply and less channeled dispersal of drifting young have more than once combined to elevate other insects (including, perhaps, even the infamous gypsy moth) to greater pest status in new habitats, whether or not they came from montane regions. Transferring any drifting species from a region in which the major weather systems that transport it travel along only one or two routes to another region with a greater variety of storm tracks will inevitably affect its dispersal pattern. But the subcontinental scale of storm-track weather obscures the important components of the aerial transport process. The smaller scale of montane processes makes these components easier to identify and analyze. Studies of montane situations can help to shape our understanding of the biometeorology of aerial transport.

Some components of the valley circulations that transport drifting insects also provide the contrasts in weather that biometeorologists can use as an outdoor laboratory. A few ridges and peaks, for example, are especially good cloud generators, spawning clouds earlier and supporting them longer than neighboring heights. These generators are the major producers of the lines of clouds we often see drifting over valleys, flattening and dissolving as they move farther from their sources of support. Although the clouds in these lines are ephemeral, the paths they follow remain remarkably constant during many different kinds of weather. Consequently, their routes can be plotted on a map, which in turn can be used to identify places in which the local climates will differ predictably from those just outside the cloud-line boundaries.

The dividing line between such climates can be remarkably sharp. One day I worked near a pole-top shelter erected by a telephone lineman to shield him from the weather while he repaired a transmission line. Throughout the afternoon, a series of small clouds drifted by, sprinkling light rain as they passed. The dividing line between the wet strip under the clouds and the dry area beyond their edges was so precisely drawn that one side of the lineman's platform was constantly wet, while the other side, only three feet away, remained dry.

Colonies of tent caterpillars were growing on the willow trees on either side of that boundary. During most of the afternoon, the insects under the line of clouds were too wet to feed, whereas those outside the boundary remained dry and continued to eat the willow foliage. For more than a month during that spring, the cloud line developed almost daily in that locality. Eventually, the recurring rain and lack of solar heat so hampered the growth of the caterpillars under the cloud line that most of them died before the end of their larval stage. In contrast, the caterpillars living beyond the edge of the cloud line grew sufficiently well to complete their development.

Although not every cloud-line boundary is so precisely drawn, the predictable recurrence of cloud lines in many kinds of weather makes them invaluable during experiments with insects in natural settings. In a previous article on the responses of insects to polarized light ("A Special Light to Steer By," December 1974), I described how drifting clouds could be used as a kind of "on–off" switch, alternately passing and blocking polarized light from the zenith. The same type of switching mechanism can be used to determine the effects of rainfall or solar heating. When the clouds are sufficiently large, they can even be used to study the effects of the rapid fluctuations in atmospheric pressure that accompany their passage.

There are so many biometeorological possibilities, in fact, that cloud lines and the mountains that spawn them offer unlimited research opportunities. They have certainly provided me with a lifetime of fascinating observations, each trip to the high country stimulating new questions about this special environment and the animals that inhabit it. □

Alternating winter invasions of Pacific and Arctic air damaged lodgepole pines along this red belt above a Jasper Park campground.

William G. Wellington

The Slow Death of Coral Reefs

by Ralph Mitchell and Hugh Ducklow

As each polyp attempts to free itself of oil, myriads of bacteria invade it

Coral reefs are among the most productive and diverse of all known ecosystems. Thousands of species of fish, mollusks, crustaceans, worms, and algae depend on these complex coastal habitats built up by myriads of coral skeletons. In the reef, masses of these skeletons, often hundreds of feet deep and miles long, are covered by a delicate layer of living polyps. This sprawling, living surface carries out the normal activities of life—feeding, growth, reproduction—all the while secreting limestone skeletons upon which other corals may grow in the future.

The surface of a coral reef is fragile and even slight disturbances may upset it. When this occurs the tightly knit reef ecosystem may disappear. Natural disturbances such as unusually low tides or the influx of a new species may result in significant alterations to a reef community, but such disturbances are infrequent.

Man's activities, however, frequently threaten the coral reefs. In some parts of the world, outright destruction of reefs has occurred, for example, the dynamiting of coral by the cement industry in Sri Lanka (Ceylon), but elsewhere the threat of pollution is far more insidious. In Hawaii and the Virgin Islands, sewage effluent discharged near reef areas has resulted in the enrichment of the normally low-nutrient-level reef waters and the consequent death of corals. Thermal pollution resulting from the release of power plant coolant in Hawaii has killed off coral reefs there. Sediments disturbed during dredging operations are choking the reefs of the Florida Keys (see *Natural History*, August-September 1973). Some coral species in Bermuda are dying off as a result of a type of bacterial infection that causes a progressive line of black slime on the corals that are being killed. South Pacific reefs are being devoured by the crown-of-thorns starfish, which is experiencing an enormous population explosion. The cause of the increase has not been determined, but scientists have not ruled out man's activities. And a proposed sea-level canal through Panama could expose the Caribbean corals to an invasion of the predatory starfish.

No reef has yet experienced a large oil spill, but many reefs are exposed to chronic oil pollution. Recent research has indicated that even very low levels of oil or pesticides can set in motion processes fatal to corals.

In the past few years several groups of biologists, including scientists from our laboratory at Harvard University, have focused on the pollution ecology of the Red Sea coral reefs at Elat, Israel, on the Gulf of Aqaba. These reefs contain more than 100 species of corals, and certain areas possess the most diverse collections of coral species anywhere. The diversity is regulated by periodic catastrophic low tides—a result of the interplay between lunar cycles and randomly fluctuating meteorological and hydrological factors—which prevent a few dominant species from taking over the whole reef. The tides are unpredictable and seem to occur several times each century.

One important aspect of pollution research at Elat concerns the impact of the city on the reefs. Surrounded by the barren Sinai and Negev deserts, the Red Sea is not subject to terrestrial influences. In the absence of such influences, we have been able to pinpoint the various kinds of urban pollution and their effects upon the coral reefs at Elat. Situated in the Sinai peninsula, the ancient port of Elat is Israel's gateway to the Indian Ocean and the East. From this rapidly expanding port city, Israel exports phosphate fertilizer from the Dead Sea works and imports oil from Iran. The Gulf of Aqaba, which is only a few miles wide, is thus exposed to oil and phosphate pollution from tanker and freighter operations.

The recent growth of Elat has already resulted in the death of one mile-long reef tract near the port. Ironically, this reef was originally set aside as a nature reserve. This status prohibited the collection and destruction of corals by bathers; nevertheless, the reef remained vulnerable to oil drifting in from the nearby terminals. Similar operations imperil the reefs near Elat's sister port city of Aqaba, on the Jordanian side of the gulf. These reefs are being destroyed, not by large oil spills or simple oil toxicity, but by the subtle effects of chronic low-level pollution.

Marine biologists working with Prof. Lev Fishelson of Tel-Aviv University have investigated the effects of oil pollution at Elat. One of Fishelson's colleagues, Yossi Loya, has documented the effect of oil on the


Lev Fishelson

ability of coral reefs to recover after an abnormally low tide. Normally, the corals remain underwater at low tide or are only briefly exposed to the air. During September 1970, however, the combination of low tides and unusually strong monsoon winds exposed coral heads for two hours each day over a period of four to five days. The hot desert sun caused desiccation and massive mortality. After such a kill-off, repopulation is effected through the release by deeper-water corals of larvae that settle in shallow areas.

Loya monitored the recovery of these shallow reefs as the corals recolonized the barren area. By comparing polluted with unpolluted reef areas, he found that oil and phosphate pollution in the Gulf of Aqaba prevented the corals in the polluted areas from returning to their former abundance and diversity. The unpolluted reefs, however, fully recovered their former state in only five years. One reason for this difference is that phosphates—from fertilizer blown over the reefs from the port area—apparently stimulate the growth of benthic algae that prevent the settlement of coral larvae. Corals are further prevented from recolonizing the

A series of abnormally low tides in 1970 killed most of the corals on this reef near Elat. (The living corals are dark brown.) Due to oil pollution, coral larvae cannot repopulate the reef.

denuded areas because the chronic low levels of oil (fewer than 100 parts per million) inhibit the formation of reproductive organs and production of larvae by the corals. The Gulf of Aqaba has not yet experienced a major oil spill; if one were to occur, the reefs would not only be destroyed but their recovery would be retarded or prevented by the constant low-level pollution.

While Fishelson and Loya have observed that low-level pollution effectively prevents a reef's recovery, our investigations of the reefs suggest how low concentrations of pollutants can affect the delicate relationship between corals and marine bacteria. Under normal conditions, coral polyps are constantly bombarded by sand and other sediments, which are churned up by wind and water currents as well as by fish and other marine animals. Polyps continually release mucous compounds of polysaccharides, proteins, and fats that act to clean the sediments off their surfaces and to free their feeding tentacles.

The mucous secretions, in turn, attract bacteria that feed off them; indeed, healthy corals always harbor a specific population of bacteria. The bacterial decomposition of this mucus provides an additional food source for other reef dwellers, such as zooplankton. Thus, within the reef there exists a microcosm of coral polyps, zooxanthellae, mucus, and bacteria.

Bacteria are extremely important organisms in the breakdown of organic matter and the recyclying of nitrogen, phosphorus, carbon, and sulfur. An average drop of seawater contains about ten thousand of the organisms. About half of these possess long, thin appendages, or flagella, which beat against the water, propelling the bacterial cells along. Most bacteria capable of movement react to chemicals—a phenomenon called chemotaxis—by moving toward the source. Bacteria rely on chemotaxis to find dead food such as mucus from corals, to track down living prey, and to detect and move away from poisonous chemicals.

Corals exposed to chemical pollutants react the same way that they do if swept over by sediments: they secrete mucus to rid themselves of the foreign substances. However, there is a difference. The secretion of mucus does not relieve the irritation. The pollutant in the water continues to ir-

ritate the polyps, which respond by secreting more and more mucus. The huge quantities of mucus thus produced act as a magnet for marine microflora, and a large and diverse population of bacteria converge on the corals through chemotaxis. These predatory bacteria consume the mucus and, as the population grows, attack the coral surface, killing the polyps. Within a few days the dying coral is a mass of bacterial slime, which forms black lines similar to those seen on coral reefs off Bermuda. In both cases excessive growth of bacteria on the coral tissue probably depletes the oxygen on the surface so that hydrogen sulfide forms. The sulfide reacts with iron to produce a black line of ferrous sulfides. This coloration is not the cause of disease but only a manifestation of the result.

This type of disease is not unique to corals. We have also induced disease in seaweed and mud snails by adding chemical pollutants to water in laboratory tanks. Dover sole caught in polluted areas off the California coast have a much higher than average incidence of fin rot, suggesting that the phenomenon may be widespread. One wonders if seaweed and fish subjected to stress excrete chemicals that attract disease-causing organisms such as bacteria. If they do, then a much more subtle effect of pollution will have to be fought.

In the next half century, the world's coral reefs will probably suffer increasingly from the adverse effects of chronic pollution. Some of the largest and most productive reefs are still untouched by human activities; however, this condition will probably soon disappear. We will need to use the most sophisticated monitoring techniques available to modern chemistry if the coral reefs are not to become another victim of our attacks on nature. □

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Announcements

The new, permanent **Hall of Minerals and Gems,** located in the southwest corner of the first floor of The American Museum of Natural History, is a most spectacular and elegant exhibit, with an impressive array of minerals, gems, rocks, and meteorites. The special gem exhibit has been extended through November and includes the Bicentennial Diamond Necklace, crafted in 1776 by order of George III of England (nearly 500 diamonds totaling 330 carats); the Flaming Star, a flawless pear-shaped diamond weighing 18.52 carats: and the Golden Hope, a naturally colored, yellow cushion-cut diamond of 44.35 carats set in a diamond, gold, and platinum pin.

At the **Hayden Planetarium** of the Museum, "Follow the Sun" continues through November. This Sky Show explores the nature of our nearest star, its source of energy, the changes it undergoes, some of its influences on earth, and its place in the universe. People of antiquity worshiped the sun as a god. They followed its motion in the sky with great concern. Frightened that the sun would not rise the next day, plunging the earth into perpetual darkness and cold, they performed elaborate rituals in the hope of gaining some control over its activities. Today, astronomers with their sophisticated solar instruments follow the sun hour-by-hour. They watch for outbursts of magnetic storms, giant eruptive prominences, and violent solar flares, which send large amounts of dangerous radiation into space. Shows begin at 2:00 P.M. and 3:30 P.M. on weekdays with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children and students (special rates for groups and senior citizens).

Note: The main auditorium of the Museum will be closed to the public through January 1977 (due to renovations and the installation of air conditioning). Weekly film programs will be held in the Education Hall.

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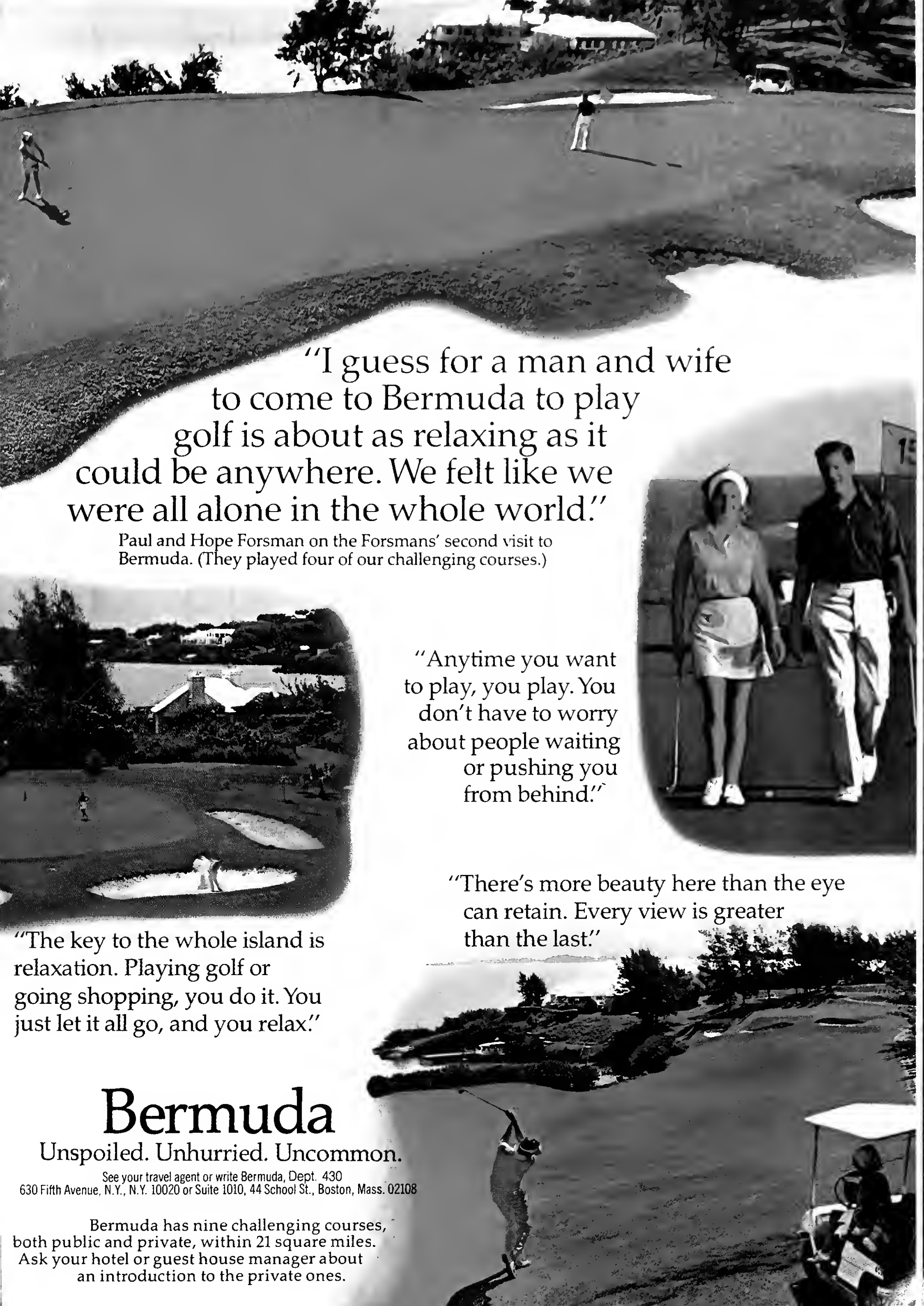
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A Matter of Taste

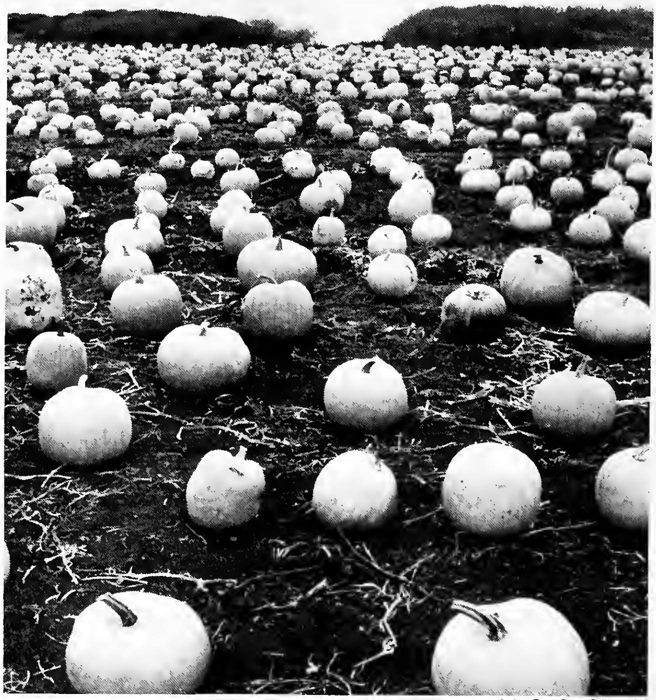
The Pumpkin Papers

An investigation into the true botanical nature of this giant orange gourd

Nearly thirty years ago, my paternal grandfather coaxed the normally trailing vine of *Cucurbita pepo* to climb up a cherry tree and grow a pumpkin. It was not a very large or pretty fruit, but it was mentioned on the garden page of the *Detroit News.* Since then I have always thought I had inherited special insight into pumpkins. Lately though, after looking into the subject more thoroughly (my research until this summer had consisted almost entirely of eating pumpkin pies and carving jack-o'-lanterns), I am not so sure.

Perhaps more than any other edible plant, the common field pumpkin, which shines from every right-thinking American's living room window on Halloween, illustrates the clash between colloquial naming and official botanical nomenclature. And that is only the beginning of the pumpkin enigma. Although you may resist the vulgar error of thinking of pumpkins as vegetables, can you so easily adjust to the scientifically unassailable notion that these giant gourds are berries?

They are, formally, berries because they are fleshy simple fruits, formed from a single pistil of the flower. They have no stones or papery cores. Grapes, tomatoes, and blueberries are typical berries: they are



Audrey Ross, Bruce Coleman, Inc.

by Raymond Sokolov

fleshy throughout and their outer layer (exocarp) is a thin skin. The pumpkin, however, is not a typical berry because it has a hard rind. Along with its cousins, the squashes, and its second cousins, the melons and cucumbers, the pumpkin is a kind of berry known as a pepo (rhymes with cheapo).

Indeed, the pumpkin is the ideal type of the pepo. You have noticed, of course, that *pepo* is its species name as well, but it is also the case that the vernacular name of the fruit, "pumpkin" itself, derives in a straight and provable line from the Greek word *pepōn*. This hoary word has meant pumpkin or melon down through the centuries. It began, in Homeric times, with the basic sense of sun-ripened or soft, was extended to mean "soft" as a term of endearment, but then settled down as the generic term for pumpkin.

But the pumpkin, you object, is not soft. It is not a summer squash picked before its rind hardens. No, it is a late-maturing, hard-edged squash. I pass over the pettifogging question of whether it is a squash or some separate category of cucurbit, since "squash" is an Algonquin term and, it seems to me, we only confuse the issue further when we try to define it too systematically. We ought also to avoid another nomenclatural puzzle: Is the pumpkin—our hard-skinned, orange field pumpkin—a winter squash? In horticultural practice it is treated like one, and it feels like one. But other varieties of the species *C. pepo* are summer squashes. And they grow in "bushes," not on vines.

Without wishing to strike a chauvinistic note, I think it is fair to say that our gargantuan native American pumpkin does not seem to fit either the "soft, sun-ripened" pepo role or match its summery species-mates because it is a latecomer to a diverse and easily hybridizing European clan. The taxonomic and colloquial strands are now too tangled ever to sort out.

Even in Europe, chaos reigns. Are French people sure what they mean when they say *courge* and *citrouille* and *potiron*? Greeks lump together all the edible gourds as *kolokithia*. Perhaps we should do this too and give up trying to remember what distinguishes pattypans from Hubbards from cocozelle from crooknecks from zucchini. But even were we to abandon these colorful terms and fall back on the gastronomically useful if imprecise distinction between hard and soft skins, we Americans would still all know one variety "by heart."

Pumpkinus americanus is simply unmistakable. The largest commercial strain, Big Max, generally reaches 150 pounds. But 300-pounders are not unknown and the 400-pound barrier is apparently not far off. Even the smaller pumpkins we buy at this time of year are so big and distinct, you don't need a botanical background to identify them at a roadside stand. In fact, this is one case where the less botany you know, the more likely you may be to locate a genuine *P. americanus*.

Any child knows what to do next. Make a circular incision around the stem, angling the knife so that this "scalp" can be replaced and won't fall in. Then scoop out the seeds, carve a face on one side of the rind, put a candle inside, and use it to scare away the dead spirits that rise up from the ground on Halloween. This apotropaic rite battens on the pumpkin because of its skull-like shape. This similarity has also inspired the derisive term, "pumpkin head," meaning dolt. Likewise, the Latin satire on the deification of the emperor Claudius is titled the "pumpkinification." This is a translation of the original title, *Apocolocyntosis,* a pun on apotheosis (deification), in which the root for the Greek word for "gourd" replaces the root for the word for "god."

Not all pumpkin metaphors are derogatory. "Pumpkins" are also VIPs. And Boston has been called Pumpkinshire, presumably from the number of pumpkins Bostonians consumed. New England remains a center of pumpkin cookery, and you will still occasionally find thin slices of pumpkin dried and hung on strings in houses there. This harks back to colonial days, when the pumpkin was a valued staple. Indians used it for flour.

Today, in America, pumpkins are eaten almost exclusively in pies in the

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Herbalist; Lima, Peru — Alan Ternes

late fall and winter. This is a shame in many ways. Excellent canned pumpkin purée is, or ought to be, available year-round. And the pumpkin is too versatile and delicious to be relegated to one ceremonial dessert and otherwise fed to livestock.

Once it has been puréed, pumpkin can be treated in much the same way as potato (see recipes below). The seeds, of course, should be eaten as a snack. To prepare, simmer in plenty of salt water for a half hour, drain, dry on paper, and toast in a low oven until lightly browned. Other international recipes for pumpkin are now available in Sheryl London's new culinary treatise, *Eggplant & Squash: A Versatile Feast* (Atheneum, $12.95). London mentions West Indian pumpkin chips, sweet and sour pumpkin, French pumpkin soup with Grand Marnier, leek and pumpkin soup from Italy, an English cream of pumpkin with ham, pumpkin ring, Indian pumpkin curry, pumpkin amandine, Armenian pumpkin and lamb shanks with mint, North African pumpkin stew with meat and cabbage, Jamaican and South American stuffed pumpkins, pumpkin jam, three pumpkin breads, and a host of pumpkin desserts.

This does not begin to exhaust the pumpkin repertoire. Moroccans make a pumpkin couscous. French provincial cooks have been known to purée shrimp and pumpkin for a milk-based soup. In the Netherlands Antilles one can find pumpkin pancakes. Mexicans fill quesadillas (tortilla turnovers) with a preparation made from pumpkin blossoms.

So much can be done with pumpkin purée that it makes an ideal medium for personal experimentation. Start with small pumpkins, however, because the purée will sour more readily than most vegetables and there is no particular advantage in making up a huge batch ahead of time. Peel the pumpkin, discard seeds and strings, and cut the flesh into chunks. Cook in simmering water to cover for 20 minutes. Drain. Mash or purée in a blender. Like mashed potato, pumpkin purée can be seasoned according to your whim, and you can quite easily give it the flavor of whatever culinary region the rest of your menu may conjure up. Garlic and oregano give you Italian pumpkin. Butter and cream take us north to the Ile de France. And so on.

And so I give you the pumpkin, enigmatic fruit, gourd of all seasons.

But before you embark on an all-pumpkin diet, I wish to counsel even mildly profeminist cooks against falling into the vulgar and ideologically regressive trap of serving soup inside a whole pumpkin. On first glance, this will seem a spectacular mode of presentation. But reflect. The whole pumpkin is a symbol of female peonage and confinement in a male world. Remember Cinderella's midnight humiliation. Or recite to yourself:

Peter, Peter Pumpkin-Eater,
Had a wife and couldn't keep her.
He put her in a pumpkin shell,
And there he kept her very well.

Giraumonade
(Martinican Pumpkin Purée)

2 tablespoons oil or lard
1 tablespoon chopped chives
1 clove garlic, peeled and chopped
2 sprigs parsley, chopped
1 pinch dried thyme
2 basil leaves, chopped
1 fresh chili pepper, chopped or 1 dried chili, crumbled
1 pound pumpkin purée

1. Heat the oil or lard in a skillet. Add all ingredients except pumpkin. Sauté until browning begins.
2. Stir in pumpkin. Mix well and serve as a side dish.

Yield: 4 servings

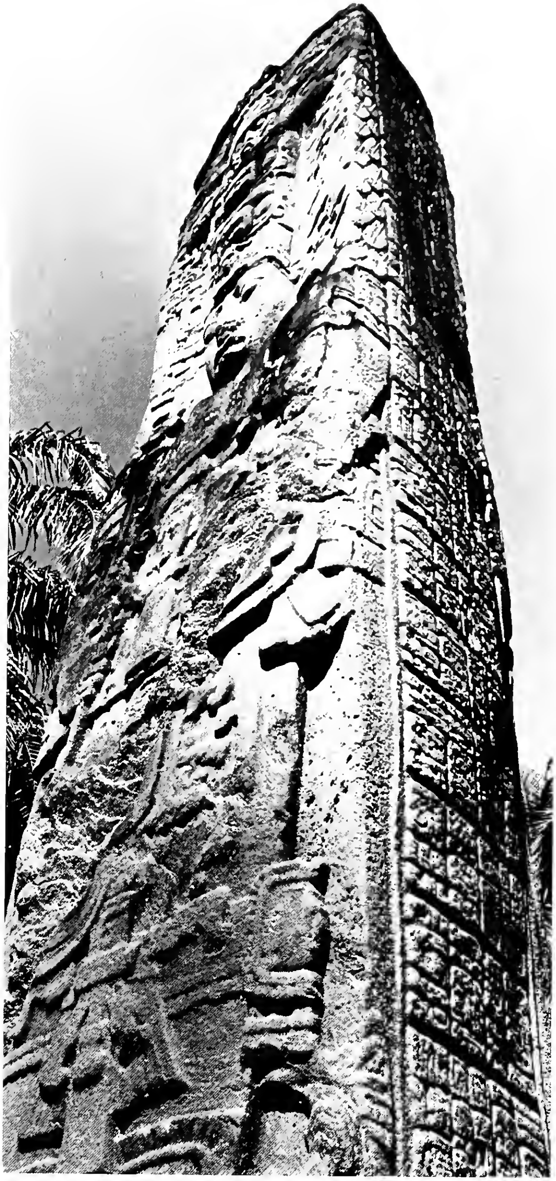
Pumpkin and Leek Soup

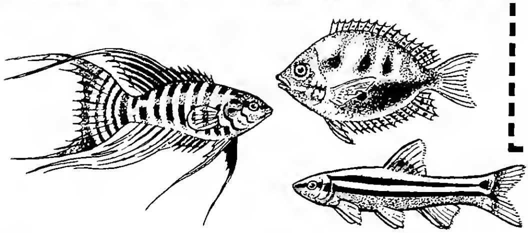
3 cups well-washed, sliced leek (white and tender green parts)
1 pound pumpkin purée or 1 pound raw pumpkin chunks
Salt
Pepper
1 cup yogurt, sour cream, or heavy cream

1. Combine leek and pumpkin with 1 quart water in a large saucepan. Bring to a boil, reduce heat, and simmer until solid ingredients are very soft, about 20 minutes.
2. Put through a food mill or blender.
3. Season to taste. Serve hot or chilled. You may stir in the yogurt, sour cream, or heavy cream before serving (at which point adjust seasoning) or pass a bowl of it separately so that it can be dolloped on by individual guests at the table.

Yield: 6 servings

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*





Stars by the Cluster

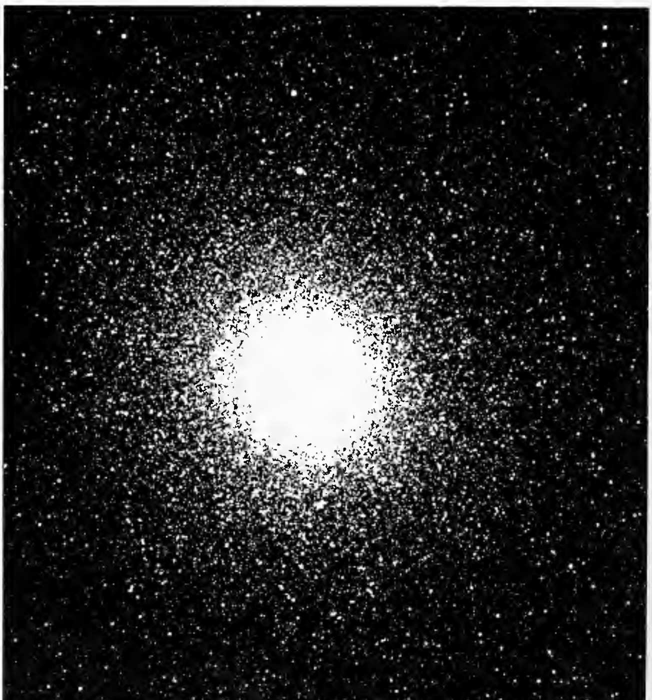
Dark clouds and recently discovered X-rays associated with dense aggregations of stars perpetuate the mysteries surrounding these objects

About 120 globular clusters have been found in our galaxy. The brightest ones are visible to the naked eye as fuzzy patches of light. Telescopes reveal them to be huge aggregations of stars, among the most spectacular sights in the heavens. Edmund Halley, the British astronomer for whom the famous comet was named, was one of the first to speculate on the size of these objects. He thought that a cluster might occupy a region "immensely great, and perhaps not less than our whole solar system." Modern observations prove that a typical globular cluster is larger by far than this eighteenth-century estimate and may include hundreds of thousands or even a few million stars within a radius of 100 light-years.

The stars on the outskirts of a globular cluster are sufficiently far from each other to enable us to photograph and study them. But in the central core, the stars are packed so closely together that our best telescopes cannot resolve them. A typical star in the center of a globular cluster may be only a third of a light-year away from its neighbors. (By contrast, the sun is four light-years from its nearest star, Proxima Centauri.) In some very dense cluster cores, the stars are still closer together. Because of the combined illumination of the surrounding stars, the inhabitants (if any) of such a region would experience evening skies much brighter than earthly nights illuminated by a full moon.

In 1714, Halley discovered the brightest globular cluster of the northern sky. He described it as just a "little patch," but a later telescopic observer wrote, "Perhaps no one ever saw it without uttering a shout of wonder." Called M 13, this object in the constellation Hercules gave rise to a long controversy over dark matter in globular clusters, which began in 1850 when William Parsons, the wealthy third earl of Rosse, examined M 13 with his private telescope at Birr Castle, Ireland. This reflector, with its six-foot-diameter metal mirror, was then by far the largest telescope ever made. With it, Lord Rosse also discovered the spiral arms of galaxies and the filaments of the Crab Nebula. On May 6 of that year he first noticed a dark streak across M 13. He observed and sketched the cluster again in 1851 and 1855 and noted two more dark lanes. One sketch, which was shown to the Royal Society, reveals three dark lanes that meet at a common point at roughly equal angles, making a pattern like an upside-down Mercedes-Benz emblem. This pattern was seen again forty years later when M 13 was photographed at Lick Observatory in California.

The Lick investigator was Edward S. Holden, a well-known American astronomer who also served as president of the University of California.



Cerro Tololo Inter-American Observatory

by Stephen P. Maran

He took seven photographs of M 13 in 1890 and 1891. The best one, made on July 28, 1891, was so good that copies of it were sent to leading observatories of the day. Holden confirmed the three-armed dark pattern and claimed he found many more examples within the cluster of three dark streaks meeting at a common point at approximately equal angles. He also found some instances of two dark streaks. He thought that the dark lanes were true channels, "empty of stars," and seemed to regard the pattern as a structural element, recurring at least a dozen times throughout the cluster like the leitmotiv of a Wagner opera.

Holden believed that the points where the dark lanes met were "centers of force" related to unknown processes that had formed the star cluster. He expected that better photographs, when they could be obtained, would reveal additional three-armed sets of dark lanes in M 13. In 1899, when improved photos were made at Lick, they failed to confirm his expectations. In fact, on the best of the 1899 pictures, a careful search of Holden's dark lanes showed that at least five dim stars were present in all but two of the lanes.

A swarm of more than half a million closely packed stars, 47 Tucanae is a bright globular cluster in the southern sky some 13,000 light-years from the earth. Seen here as photographed with a four-meter telescope in Chile, the cluster is about 12 billion years old, making it one of the oldest objects in our galaxy.

The nature of the lanes and other dark regions in globular clusters has been much debated and the arguments have been revived with new vigor in the past twenty years, during which time many more dark clouds have been found in globular clusters under study. Holden's concept of mysterious centers of force has been dropped and the idea that the lanes are simply accidental gaps in the spacing of the stars has also found few advocates. Most astronomers favor the theory that at least some of the dark regions are due to absorption of light by dust clouds. The controversy now centers on the location of these dark nebulae. Are they actually in the clusters, that is, true "intraglobular matter," or are they foreground objects, closer to us in space but seen against the bright surfaces of the distant clusters? There seem to be fundamental objections to both possibilities.

If the dark regions are foreground dust clouds, then the fact that so many of them are observed against the globular clusters leads to an estimate of the number of dark nebulae near the sun that is far too high. On the other hand, if the dark regions are actually intraglobular dust clouds, then one expects to find a great deal of gas in the clusters, because studies of the gas and dust in the galaxy have consistently shown that where diffuse matter exists in space, there is typically 100 to 1,000 times as much gas as dust. This gas is mostly composed of hydrogen. In a globular cluster, the hydrogen atoms might be electrically neutral, in which case they would emit radiation at a wavelength of 21 centimeters, which could be observed with radio telescopes. Or, alternatively, the hydrogen might be electrically charged, in which case radio waves would be emitted at wavelengths of only a few centimeters and there would also be a dim, red glow. Yet several teams of astronomers, using sensitive modern instruments, have searched since 1970 for each of these emissions in a number of globular clusters, and in no case has any radiation been found.

Also since 1970, five X-ray sources have been located in globular clusters by two NASA satellites. During 1975/76, these sources were intensively studied with five other spacecraft, including one Dutch satellite carrying an American X-ray telescope in its payload. These observations have caused a furor among astrophysicists. Most known galactic

X-ray sources are either supernova remnants (like the Crab Nebula) or so-called X-ray binary stars, and neither of these are thought likely to still exist in globular clusters. The globulars, as a class, are among the oldest objects in our galaxy and thus lack any source of young stars of the type that give rise to these two short-lived classes of X-ray source. (A supernova remnant lasts for about 100,000 years, while an X-ray binary expires in only 10,000 years or so. A typical globular cluster, on the other hand, may be 10 billion years old. Thus, any X-ray sources that formed when the cluster contained young stars would have vanished long ago.) If the known types of X-ray sources do not exist in the clusters, then the cluster X-ray sources must represent physical phenomena of new types. It is logical, therefore, to assume that they result from the unique conditions in the centers of globular clusters.

Many of the theories developed to explain the X-rays from globular clusters invoke colliding stars or black holes or both. At one time, a near collision between the sun and a passing star was proposed as the origin of the earth and other planets in our solar system. This idea was rejected when calculations showed that the chances of such a collision taking place are infinitesimal. By contrast, stars in the core of a globular cluster are so close together that collisions undoubtedly do occur. Calculations by University of Michigan astronomers indicate that a star confined to the core region has a 3 percent chance of colliding with another star during the cluster's lifetime. In the densest known cluster core, that of the globular M 80, this probability is a whopping 41 percent. About 2,700 collisions have occurred in M 80 according to the Michigan calculations. It is believed that some of the stars that undergo collisions must be black holes, since these massive objects should be concentrated at the heart of a cluster.

A black hole is the final stage of a large star that imploded when its nuclear fuel ran out and the star could no longer generate enough energy to support its outer regions. Under such circumstances, the huge mass of the star is compressed into a tiny volume, and the surface gravity becomes so intense that not even a ray of light can escape. Any matter that falls into a black hole is trapped forever and simply increases the mass of the hole.

Since a hole is invisible, it must be detected by indirect means and only one such detection has been generally accepted thus far—an object called Cygnus X-1. Nevertheless, physicists are confident that many black holes exist, and point to neutron stars (also the condensed remains of imploded stars), which were predicted by similar calculations and have been found to exist in considerable numbers.

Two kinds of black holes, "giant" and "ordinary," have figured in globular-cluster theories. The giant hole, with a mass of up to several thousand times that of the sun, might be primordial, that is, left over from the birth of the cluster itself, when a huge cloud condensed to form many stars, perhaps also producing the black hole at its center. Or it might be composed of many lesser black holes that collided and merged with each other and with normal stars. If a giant black hole were present in the heart of a cluster, it would suck in gas from surrounding space that was either shed by stars as part of normal stellar life (*see* "Missing Matter," *Natural History*, January 1976) or literally ripped off passing stars by huge tides raised on their surfaces by the gravitational force of the hole. As the gas flowed toward the black hole, it would be compressed and heated, producing the observed X-rays. Theories of this type have been published by scientists at Princeton University, the Institute for Advanced Study, and the University of California at Berkeley.

An ordinary black hole is one with about ten times the sun's mass. If located in a binary star system, it can generate X-rays when matter flows toward it from its companion star. However, X-ray binaries of this type should not exist among the old stars of globular clusters, as mentioned above. Thus, researchers have raised the question, Can new X-ray binaries be forming among the old stars of these clusters? According to George W. Clark of MIT, an authority on cosmic X-rays, the answer is yes. He points out that since even ordinary black holes are much more massive than the average star, they will tend to "lurk" near the cluster centers. There, a black hole may occasionally capture another star in a near collision, thus forming a new X-ray binary. Clark believes that the potential exists for one X-ray binary to be formed in every cluster, although

only five globular cluster X-ray sources have been found. An expert on star collisions, Jack G. Hills of the University of Michigan, disagrees, but suggests that an X-ray binary might be formed when a black hole encounters a normal binary, capturing one of its member stars while the other escapes. Hills also claims that binaries are not needed to explain the globular cluster X-ray sources, since he calculates that the tidal disruption of passing stars by an ordinary black hole can produce sufficient X-rays.

Massive black holes in globular clusters (if any exist there) might help explain the absence of gas, which puzzles observers who search for intraglobular hydrogen. At the center of a cluster, the interstellar material could be drawn into the black hole, producing the observed X-rays. In the outer regions, say two University of Maryland astronomers, the gas could be heated and blown out of the cluster in a great "stellar wind" driven by the combined ultraviolet light of the cluster stars. This might account for the presence in globular clusters of dust clouds lacking the usual large amounts of accompanying gas. Thus, there may be a link between the old problem of dark matter in globular clusters and the recent discovery that they produce powerful X-ray radiation. The occurrence of black holes would also mean that centers of force exist in the clusters, although not in the form imagined by Holden eighty-five years ago.

In the past year, a new series of findings poses additional mysteries concerning globular clusters. The Dutch satellite and *SAS-3*, one of NASA's, have detected rapid X-ray bursts (lasting only seconds) from cluster sources, and Soviet astronomers now say that in 1971 they observed similar events in two clusters with their *Cosmos 428* spacecraft. Further, similar bursts have been recorded from directions in space where no globular clusters are seen. Attempts thus far to explain these bursts have been most unsatisfactory. It appears that additional discoveries raise more questions than they answer as astronomers extend their studies of the remarkable globular clusters.

Stephen P. Maran is at the University of California in Los Angeles on temporary assignment from NASA's Goddard Space Flight Center in Greenbelt, Maryland, to study stars.

An Energetic Call for Socialism

The Poverty of Power, by Barry Commoner. *Alfred A. Knopf, Inc., $10.00; 382 pp.*

The first law of thermodynamics ordains that the total amount of energy in this universe of ours is constant. Energy can neither be created nor destroyed. A weight falling toward the floor builds up energy yet, splat, there it ultimately lies immobile. The energy account remains in balance, however, because an equivalent amount of heat was generated by the impact. Ah, suppose that we could harness that heat and use it to raise the weight, let it fall again, harness the heat—why, we may be on to perpetual motion. We are never going to do it.

Why should we not succeed if energy is a constant? Because what we intend to do is to get work out of energy, at which point we run afoul of the second law of thermodynamics. That is to say, uncoordinated energy does not spontaneously transform itself into coordinated energy. We shall have to harness the heat to get work out of it, which requires an engine. Even our most perfect engine will lose some of the heat between the source and the final drive shaft. While no energy is lost by the universe, we mortals, of necessity, waste a great deal of energy trying to put it to work for us.

Our conventional sources of energy, oil and coal, are in finite supply. We should use them so as to get the most work we can out of every ton we consume. "Waste not, want not" is simple Yankee prudence. Better yet, such a strategy will improve the environment because the energy we waste tends to turn up in such forms as thermal pollution. What we need to do then is to match fuels to the jobs we have in mind. It makes little sense to burn tons of oil to produce electricity and then, after the generating plant releases untold amounts of waste heat into the atmosphere and a great deal of the electrical energy is lost in the transmission process, use the resultant electrical energy to heat a house. It is absurd to build a nuclear reactor to boil water to create steam to power a generator to produce electrical energy so that some homeowner can turn around and use the resultant product to boil water on his electric stove. We don't need all this fuss and waste in order to create heat all over again. We should employ electricity where we need it, as in the case of powering motors. Thus Dr. Commoner articulates his own axiom: "Energy is efficiently used when the quality of the source is matched to the quality demanded by the task."

What should we be doing? First and foremost, we should not despair. We have on hand domestic oil reserves to see us through the next fifty or sixty years if we don't fritter them away. Efficiency dictates then that we replace the oil burner with the diesel-powered heat pump to heat homes. We must make more use of electric trains to transport commuters. With both expedients we can actually use what has hitherto been waste to gain added dividends. We can tap the exhaust from the heat pump's diesel motor for extra heat and we can chan-

nel the exhaust of coal-powered generating plants to heat center-city apartment blocks.

These tactics, designed to buy time, are not calculated to see the emergence of a plutonium economy. Uranium being itself in finite supply, nuclear energy ultimately entails reliance on reactors powered by plutonium. Plutonium is so dangerous a substance that, let loose into the environment by an accident, the consequences cannot fairly be gauged. Worse yet, it can be made into a bomb by people working with material available at their local hardware store and an ordinary laboratory-supply house.

Our ultimate strategy should be calculated to see us obtaining our energy from renewable resources fifty years hence. The only renewable source of energy is the sun. But isn't this a pipe dream? Not according to Commoner, who presents a case for the proposition that we can ultimately "obtain all, or nearly all, of our energy from the sun." This is not all. "When the facts are known, however, it turns out that solar energy can not only replace a good deal, and eventually all, of our present consumption of conventional fuels—and eliminate that much environmental pollution—but can also reverse the trend toward escalating energy costs that is so seriously affecting the economic system."

We reach a critical point with this reference to the economic system. What I have done up to now is try to illustrate the exciting flavor of Commoner's discussion of energy and its

uses. There is much more to the book than that, however, because he also examines why we should have come to be involved building nuclear reactors in order that people can brew their breakfast tea. It boils down to a strong case for the proposition that we have no rational over-all energy program. What we do have are programs designed by oil companies and electric utilities to merchandise their products in order to make a profit. The future may be even bleaker if we continue to treat energy resources as mere commodities to be exchanged for profit. Extracting oil and coal is going to require ever increasing investment in plants and equipment, and the necessary capital is already being exacted from consumers as a hidden increment in the escalating price of fuel. We shall all ultimately be colder, poorer, and likely jobless because our industrial society cannot continue to function without relatively cheap energy.

Recall now that Commoner foresees the sun as the ultimate solution of the energy problem. Solar energy is going to become extremely valuable to us. Social need will create this value so that, unlike oil, we should not recognize solar energy as anyone's private property. In short, we need to socialize our energy sources if we are not going to make another hash of it. So excited does the good doctor become on this score that he seriously treats with Marx and comes out foursquare for socialism in lieu of capitalism. This part of the book, obviously, has not been met with rave reviews. The headline writers for the *New York Times* have unwittingly distilled conventional wisdom if we read the daily and weekend editions of their wit seriatim: "Thermodynamic Socialism: Read it for the science, pass up the economics."

What is one to make of all this? On the one hand, it may be that Commoner has authored a self-fulfilling prophecy. The economist Joseph Schumpeter did predict, after all, that capitalism would collapse precisely because people would cease to believe in it. On the other hand, the author's "socialism" may be a fad. In this regard the reader should reflect on an axiom of sociologist Henri Le-

febvre, someone actually familiar with Marxism. "Thus the bourgeoisie swings wildly. . . . Malthusianism is its ideology in periods of depression. . . . Technological snobbery becomes its ideology in periods of expansion. . . . Both ideologies reflect the current level of productive forces."

Read the book—it is a "must"—and make your own judgment. Let me reveal my own reaction. Commoner's urge to order worries me in light of his own reliance on the second law of thermodynamics. After all, that law paraphrases entropy, the notion that the universe is becoming less and less ordered. Humankind can stand only so much disorder before it, by hook or crook, imposes some fabricated notion of order. I am reminded, therefore, of Rubashov's reflections in Koestler's *Darkness at Noon*. "A people's capacity to govern itself democratically is thus proportionate to the degree of its understanding of the structure and functioning of the whole social body. . . . The mistake of socialist theory was to believe that the level of mass-consciousness rose constantly and steadily." If entropy functions to complicate the economic and social world so that, increasingly, people find it difficult to understand, then Rubashov's dictum has to be taken seriously if we posit "socialism" as an answer to our problems. It is worth noting that it is the United Kingdom and the Soviet Union that are producing SSTs, so that "socialist" societies are not necessarily environmentally superconscious societies.

Frankly, I have been very worried for some time at how sincere concern over the environment can lead to a belief in "right" answers and a wish for a government able to impose those right answers. The behavior of the energy merchants merits the lambasting they get from Dr. Commoner. I feel uneasy here, however, because Commoner's certainties may be a prelude, not to democratic socialism, but to national socialism.

E.F. Roberts is a professor at Cornell University Law School, where he teaches environmental law and land-use planning.

Celestial Events

by Thomas D. Nicholson

Sun and Moon After crossing over the equator in late September, the sun continues to move rapidly southward above the earth. It is in Virgo throughout the month, passing into the stars of Libra by November 1. On October 23, it encounters the new moon, producing a solar eclipse, total along a narrow path extending from east Africa to southern Australia, and partial in a broad area of the Indian and Pacific oceans.

The moon will be a prominent evening object through the first ten days of October; a morning object from then until about the 20th. It will show up again in the evening sky from late October through the first week and a half of November. It will be full on October 7, last-quarter on October 16, new on October 23, and first-quarter on October 29. In early November, full moon is on the 6th, last-quarter on the 14th. The penumbral eclipse of the moon on November 6 (when the earth blocks some sunlight from the moon) occurs mostly after moonrise in North America, producing little discernible change in the moon's appearance.

Stars and Planets Jupiter, in Taurus, is the only planet one can see on the evening Star Map. It rises shortly after sundown and remains visible throughout the night, brighter than any other starlike object. Venus—the prominent object you see in the west during twilight—is brighter than Jupiter, but it sets too early to appear on the map. Mars, although still an evening object, is not in a good position for viewing. Mercury and Saturn are morning stars. Saturn can be seen in the east, in Cancer, any morning after midnight; look for Mercury low in the east during morning twilight until mid-October.

October 7: Mercury is at its greatest distance to the right of the sun (a very favorable morning elongation). Today's full moon is the hunter's moon.

October 10: Moon at apogee, farthest from earth.

October 11: The bright object near the moon tonight is Jupiter. The two separate slowly during the night.

October 18: At dawn, look for Saturn above the crescent moon.

October 21: The Orionid meteor shower (about 25 per hour, often bright) reaches maximum this morning.

October 23: Eclipse of the sun, not visible in America. Perigee moon, nearest earth, occurs eight hours past new, so look for strong tides (perigee spring tides).

October 24: Communities on daylight time move clocks back one hour this morning, returning to standard time.

October 24–25: The crescent moon moves from right to left above Venus.

October 27: The star near Venus is Antares, in Scorpius.

November 4: The weak (15 per hour) and dim Taurid meteors reach maximum.

November 6: Moon at apogee. Penumbral lunar eclipse.

November 7: Jupiter is again very near the moon. Mercury, at superior conjunction (in line with but beyond the sun), enters the evening sky.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 11:15 P.M. on October 1; 10:20 P.M. on October 15; 9:15 P.M. on October 31; and 8:15 P.M. on November 15; but it can be used for an hour before and after those times.

Helmut Wimmer

If we don't deal now with the energy problem in its entirety, we may soon be facing an even bigger problem–how to sustain our economy and our social structures when there's not enough energy to go around.

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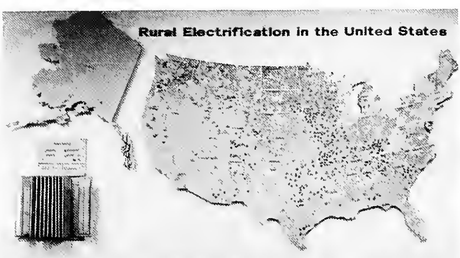

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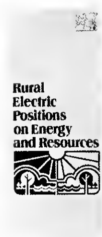

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Additional Reading

Malnutrition and Learning (p. 6)

Malnutrition, Learning and Behavior, edited by Nevin S. Scrimshaw and John E. Gordon (Cambridge: MIT Press, 1968, $15), is a good entry point into the disparate literature of this field. Review articles on relationships between nutrition and intellectual development include Bonnie J. Kaplan's "Malnutrition and Mental Deficiency" (*Psychological Bulletin*, 1972, vol. 78, pp. 321–34), "Nutrition and Learning," by H. F. Eichenwald and P. C. Fry (*Science*, 1969, vol. 163, pp. 644–48), and "Protein-Calorie Malnutrition in Children and Its Relation to Psychological Development and Behavior," by Michael C. Latham (*Physiological Reviews*, 1974, vol. 54, pp. 541–65). "Nutritional and Environmental Interactions in the Behavioral Development of the Rat: Long-Term Effects," by David A. Levitsky and Richard H. Barnes (*Science*, 1972, vol. 176, pp. 68–71), and "Malnutrition and Environmental Enrichment by Early Adoption," by Myron Winick et al. (*Science*, 1975, vol. 190, pp. 1173–75), show the potential for environmental compensation of nutritional deficits. The Mexican study described by Levitsky, "The Importance of Nutrition and Stimuli on Child Mental and Social Development," by Alfonso Chavez et al., was published in *Early Malnutrition and Mental Development*, edited by J. Cravioto (Stockholm: Almqvist and Wiksell, 1974, pp. 211–25). In their contribution, "Early Undernutrition, Brain Development and Behavior," to *Ethology and Development*, edited by S. A. Barnett (London: William Heinemann, 1972), John Dobbing and J. L. Smart critically reviewed the effects of malnutrition on structural and functional changes in neural organization.

Malaria and Economics (p. 36)

Malarial biology is covered in P.C.C. Garnham's *Malaria Parasites and Other Haemosporidia* (Oxford: Blackwell Scientific Publications, 1966) and in his paperback text, *Progress in Parasitology* (Atlantic Highlands: Humanities Press, 1971, $3.25). The battle against this disease is documented in Greer Williams's *The Plague Killers* (New York: Charles Scribner's Sons, 1969, $6.95) and Malcolm Watson's *African Highway: The Battle for Health in Central Africa* (Mys-

tic: Lawrence Verry, 1953). *The Careless Technology: Ecology and International Development*, edited by M. Taghi Farvar and John P. Milton (Garden City: Doubleday, 1972, $25), the proceedings of an international conference, deals with the disruption of naturally balanced ecosystems by the implementation of plans aimed at economic development. "Effects of Irrigation on Mosquito Populations and Mosquito-borne Disease in Man, with Particular Reference to Rice-field Extension," by G. Surtees (*International Journal of Environmental Studies*, 1970, vol. 1, pp. 35–42), illustrates problems that can arise from such developmental schemes.

Bermuda Birds (p. 48)

Kenneth L. Crowell's "Reduced Interspecific Competition Among the Birds of Bermuda" (*Ecology*, 1962, vol. 43, pp. 75–88) provides additional details of his field studies of this island habitat; "Down East Mice" (*Natural History*, October 1975, pp. 34–39) deals with another facet of Crowell's research on island biogeography and population dynamics. C. S. Elton's *The Ecology of Invasions by Animals and Plants* (New York: John Wiley & Sons, 1966, $5) analyzes the impact of new species on ecosystem diversity. Richard A. Slaughter, in *Birds in Bermuda* (Hamilton: Bermuda Bookstore, 1975), complements

his excellent photographs with a poetic plea for maintaining the integrity of natural ecosystems. David B. Wingate's *A Check List and Guide to the Birds of Bermuda* (Hamilton: The Island Press, 1973), an annotated list of the island's breeding birds, also contains detailed charts of the occurrence of all 320 transient and resident species.

National Parks Supplement (p. 57)

See pages 86–87.

Primate Conservation (p. 90)

Thomas T. Struhsaker's "Rain Forest Conservation in Africa" (*Primates*, 1972, vol. 13, pp. 103–9) stresses the need for rain forest parks to preserve the natural habitats of many endangered primate species. Several *Natural History* articles, such as R. D. Martin's "Ascent of the Primates (March 1975, pp. 52–61) and "Strategies of Reproduction" (November 1975, pp. 48–57) and Katherine M. Homewood's "Monkey on a Riverbank" (January 1975, pp. 68–73), have addressed the ecological strategies of threatened species. *Primate Utilization and Conservation*, edited by D. Lindburg and G. Bermant (New York: John Wiley & Sons, 1975), collects nearly a dozen papers from a symposium, which are exemplified by primate ecologist J. Stephen Gartlan's "The African Coastal Rain Forest and Its Primates: Threatened Resources" (pp. 67–82) and Orville A. Smith's "Production of Specialized Laboratory Primates, with Consideration for Primate Conservation" (pp. 127–39). "Problems and Potentials for Primate Biology and Conservation in the New World," by Paul G. Heltne and Richard W. Thorington, Jr., is representative of the papers in *Neotropical Primates: Field Studies and Conservation*, edited by Thorington and Heltne (Washington, National Academy of Sciences, 1976), a symposium directed to conserving New World species and their ecosystems.

Mountain Biometeorology (p. 100)

Maurice G. Brooks's *The Life of the Mountains* (New York: McGraw-Hill, 1967) provides a general biological survey. *Climates of North America*, edited by Reid A. Bryson and F. Kenneth Hare (New York: American Elsevier Publishing, 1974), includes excellent descriptions of the effects of mountain ranges on weather systems. Eric Sloane's slim volume, *Clouds, Air and Wind* (New York: Devin-Adair, 1941), provides more information on cloud forms than many newer, more formal texts. In a paper coauthored with W. R. Henson and W. G. Wellington, Ronald W. Stark reports on the "Effects of the Weather of the Coldest Month on Winter Mortality of the Lodgepole Needle Miner in Banff National Park" (*Canadian Entomologist*, 1954, vol. 86, pp. 13–19). Information

about the red belt phenomenon is found in Walter R. Henson's "Chinook Winds and Red Belt Injury to Lodgepole Pine in the Rocky Mountain Parks Area of Canada" (*Forestry Chronicle*, 1952, vol. 28, pp. 62–64). Cloud-line studies are reported in William G. Wellington's *Canadian Entomologist* article: "The Use of Cloud Patterns to Outline Areas with Different Climates During Population Studies" (1965, vol. 97, pp. 617–31).

Coral Reef Pollution (p. 106)

Two beautifully illustrated introductions to coral reefs are Jacques Cousteau and Philippe Diole's *Life and Death in a Coral Sea* (Garden City: Doubleday, 1971, $9.95) and Douglas Faulkner's *The Living Reef* (New York: Quadrangle, 1974). "Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll," by Howard T. Odum and Eugene P. Odum (*Ecological Monographs*, 1955, vol. 25, pp. 291–320), is a landmark study in reef research, demonstrating that a coral reef community functions as an "oasis" in a nutrient-poor ocean. Peter Garrett and Hugh Ducklow discuss bacteria–coral interactions in "Coral Diseases in Bermuda" (*Nature*, 1975, vol. 253, pp. 349–50), and an account of reef destruction is found in Gilbert L. Voss's "Sickness and Death in Florida's Coral Reefs" (*Natural History*, August-September 1973, pp. 40–47). Research details from the Red Sea sites described in the current *Natural History* piece may be found in Yossi Loya's "Possible Effects of Water Pollution on the Community Structure of Red Sea Corals" (*Marine Biology*, 1975, vol. 29, pp. 177–85) and "Recolonization of Red Sea Corals Affected by Natural Catastrophes and Man-made Perturbations" (*Ecology*, 1976, vol. 57, pp. 278–89) and Lev Fishelson's "Ecological and Biological Phenomena Influencing Coral-Species Composition on the Reef Tables at Eilat (Gulf of Aqaba, Red Sea)" (*Marine Biology*, 1973, vol. 19, pp. 183–96).

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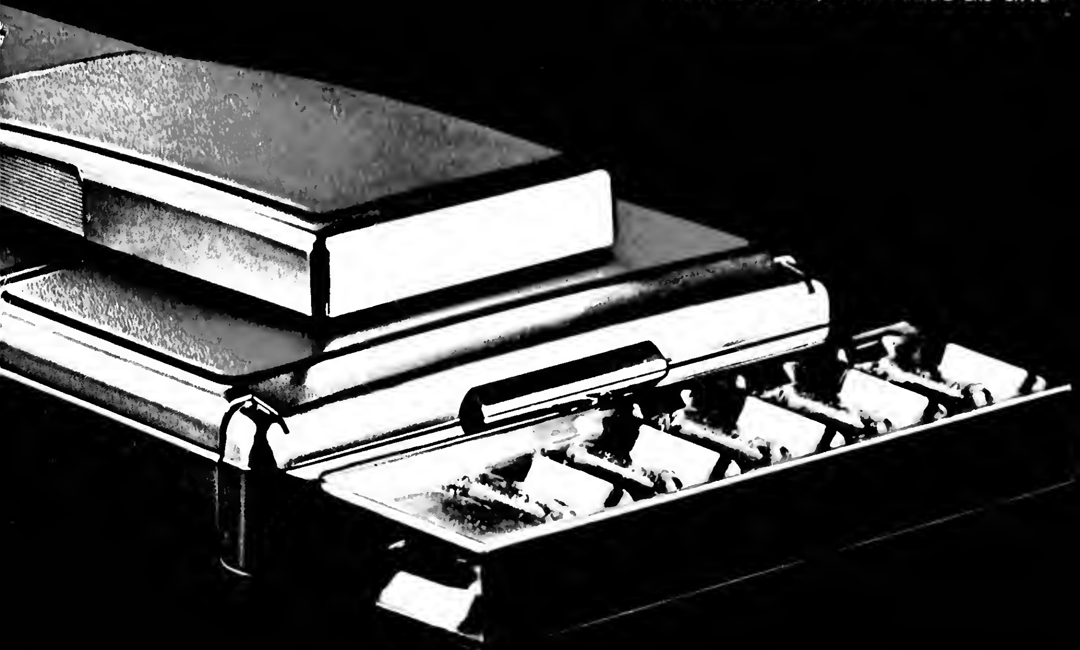

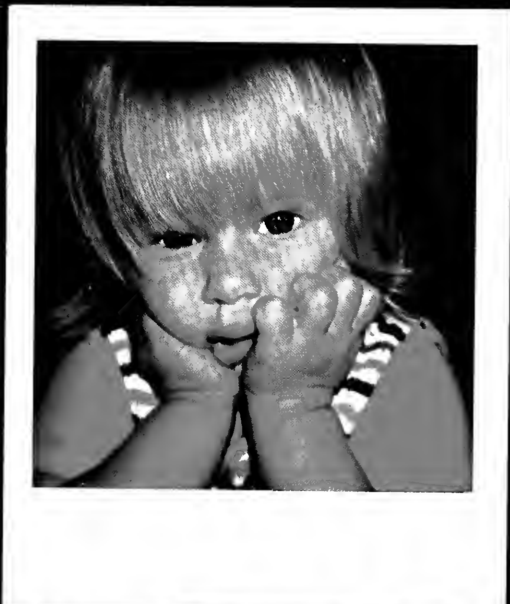

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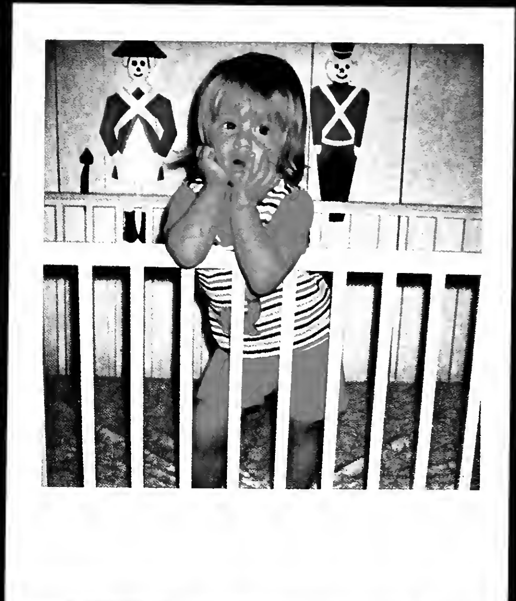

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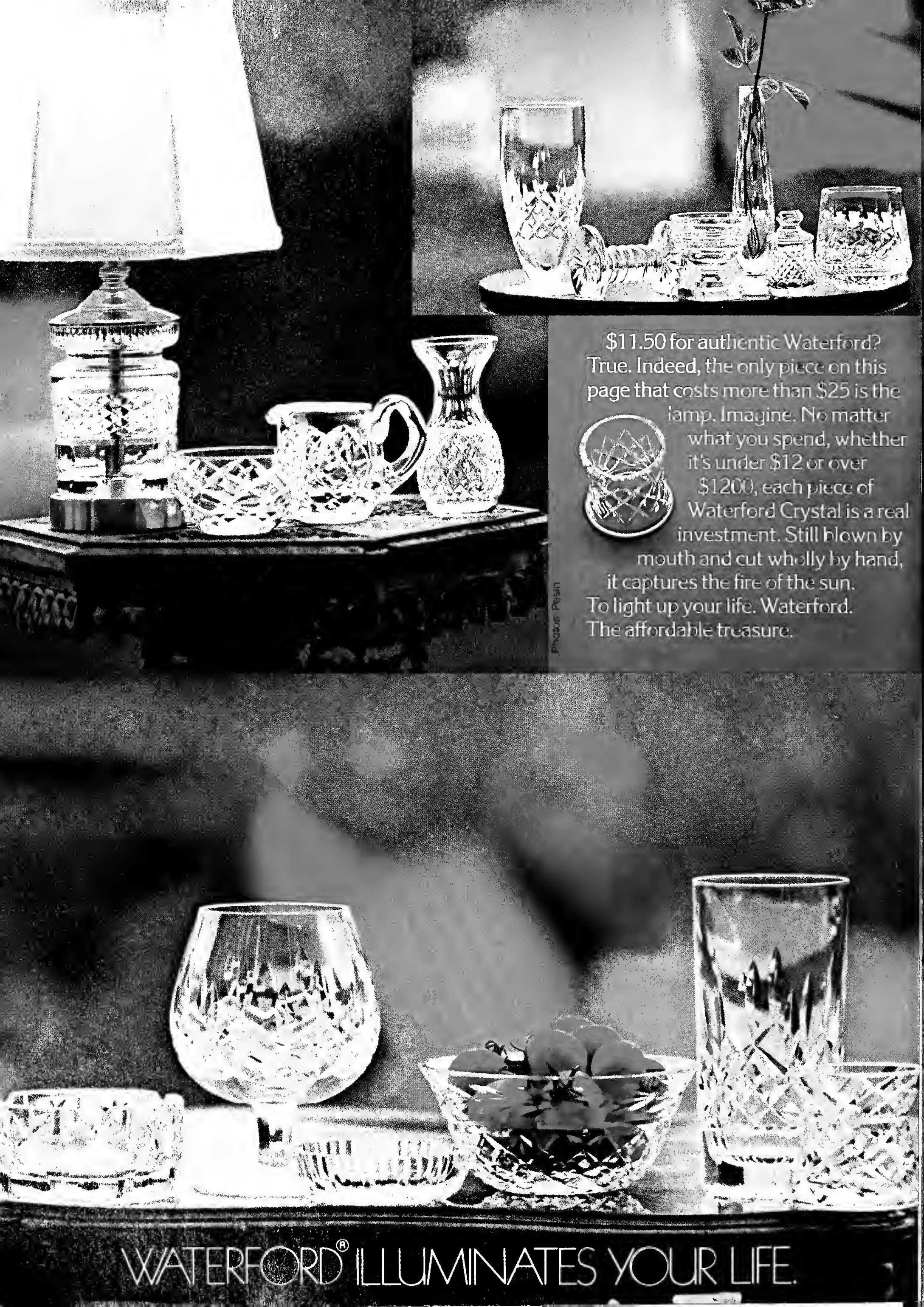
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Incorporating Nature Magazine
Vol. LXXXV, No. 9
November 1976

The American Museum of Natural History
Robert G. Goelet, President
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Cover: *A jet of hot gas erupts from an active region on the sun's surface. This color-enhanced black-and-white photograph was taken at Big Bear Solar Observatory. "The Turbulent Sun" begins on page 54.*

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Authors

One of the most pleasant aspects of **Shepard Forman**'s fifteen-month-field work experience among the Makassae in Portuguese Timor was learning self-sufficiency. Isolated living conditions and a subsistence economy made it necessary for Forman, his wife, and their two young children, to raise virtually all their own food. Forman also built their bamboo house, as well as a garage for a temperamental army Jeep, a veteran of several World War II campaigns. Forman now teaches anthropology at the University of Michigan. He plans to continue studying the history of the colonization of Timor, as well as the religious ideology of Brazilian and Portuguese peasant societies, a project that he began four years ago.

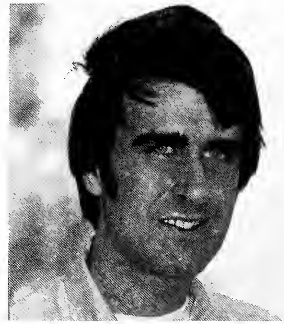
Lee Waian reports that "after observing the big 'white hawk' hovering over the coastal fields of southern California, he dropped a budding career interest in marine ecology and began studying the white-tailed kite." His ongoing research into the behavioral ecology of this bird of prey began in 1965. An independent environmental consultant, Waian is also investigating other grassland predator–prey relationships. Among his avocations, film making ranks first, followed by a near addiction to fly-fishing.

The history of the first live gorilla brought to this country came to light entirely by accident when **John C. Whittaker** (right), then an anthropology student at Cornell University, happened upon the gorilla's dusty and unmarked file while gathering material for a thesis on Cornell's anthropological collections. Now a graduate student at the University of Arizona, Whittaker collaborated with **Kenneth A. R. Kennedy** (left) in sorting through the details of the gorilla's life and the body of scientific knowledge that resulted. Kennedy, a biological anthropologist, teaches at Cornell University, where his major fields of study are primate evolution and the history of early man in South Asia.

Born in 1957, in Marsabit District, Kenya, **Hussein Adan Isack**, a member of the pastoral Borans, spent his early youth tending his father's cattle and sheep. At nine, he was taken to primary school away from home. He writes, "Everything was new to me—lorries, shops, cigarettes, sewing machines." A strong interest in wildlife developed when he began his studies at the Kangaru Secondary Boys School in the Embu District, where he is at present in the fourth form. He is a member of the Kangaru Wildlife Club and has joined the President's Award Scheme, which tests young people's endurance under harsh conditions. He recently won the Award Scheme gold medal in the expedition category. Isack hopes to go on to college to study wildlife management and conservation. His article in this issue won first prize in the Wildlife Clubs of Kenya Annual Essay Competition.

An active outdoorsman, **Denis Hayes** has worked for the environmental movement since graduating from Stanford University in 1969. He was national coordinator of Environmental Action, Inc., which organized the first Earth Day in 1970, and served as director of the Illinois State Energy Office. At present, Hayes is a senior researcher at Worldwatch Institute, a new, globally oriented environmental organization based in Washington, D.C. His search for "benign and sustainable energy options" as alternatives to nuclear power led him to investigate ways in which waste can be recycled into productive energy. The research will be published in a forthcoming book, *Rays of Hope*, from which this article is excerpted.

John A. Eddy has been on the staff of the High Altitude Observatory in Boulder, Colorado, for thirteen years. That time has been largely spent in making observations of the sun and in teaching astronomy at the University of Colorado at Boulder. A graduate of the United States Naval Academy, Eddy also has a Ph.D. in astrogeophysics from the University of Colorado. He will shortly join the Harvard College Observatory/Smithsonian Astrophysical Observatory as a visiting fellow to conduct a research program on the behavior of the sun during the last hundred years. In addition to his work on the sun, Eddy has investigated astroarcheology and the use of medicine wheels by early American Indians. He served as consultant on the Sun Supplement in this issue.



Roger K. Ulrich is an associate professor of astronomy at the University of California, Los Angeles. A 1963 graduate of the University of California, Berkeley, he obtained a Ph.D. in astronomy from that university in 1968. A graduate seminar on solar oscillations initially aroused his interest in the topic, which he has been investigating for several years. He is also engaged in research on the formation of stars and the origin of X-ray stars in particular. Field work has taken Ulrich to Sacramento Peak Observatory in Sunspot, New Mexico.

J. David Bohlin is a research physicist in solar astronomy at the Naval Research Laboratory in Washington, D.C., where he is currently engaged in the analysis of *Skylab* solar data with an emphasis on coronal holes. Bohlin did his undergraduate work at Wabash College, Crawfordsville, Indiana, and acquired a Ph.D. in solar physics from the University of Colorado. He has done field work at the solar patrol telescope in Tel Aviv, Israel, and at Big Bear Solar Observatory in the San Bernadino Mountains of California.

Peter A. Sturrock is professor of space science and astrophysics at Stanford University. Born in England, although now an American citizen, he did his undergraduate and graduate studies at Cambridge University from which he received a Ph.D. in mathematics in 1951. Sturrock first became interested in solar flares in 1963, when he participated in a symposium on the subject held under the auspices of NASA. Among the organizations to which he belongs are the International Astronomical Union, the American Physical Society, the American Geophysical Union, the American Astronomical Society, and the Royal Astronomical Society.

John N. Bahcall is on the faculty of the School of Natural Sciences of the Institute for Advanced Study in Princeton, New Jersey. He was an undergraduate at the University of California, Berkeley, and received a Ph.D. in physics from Harvard University in 1961. Bahcall has been concerned with what he calls the "solar neutrino problem" for about fifteen years and plans to continue his efforts to solve it. He was elected to the National Academy of Sciences in April of this year.

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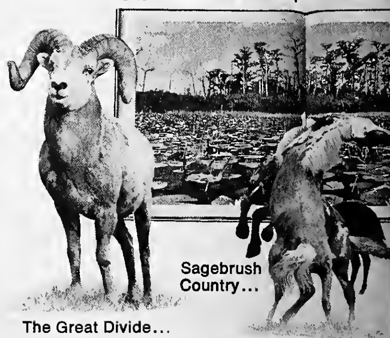

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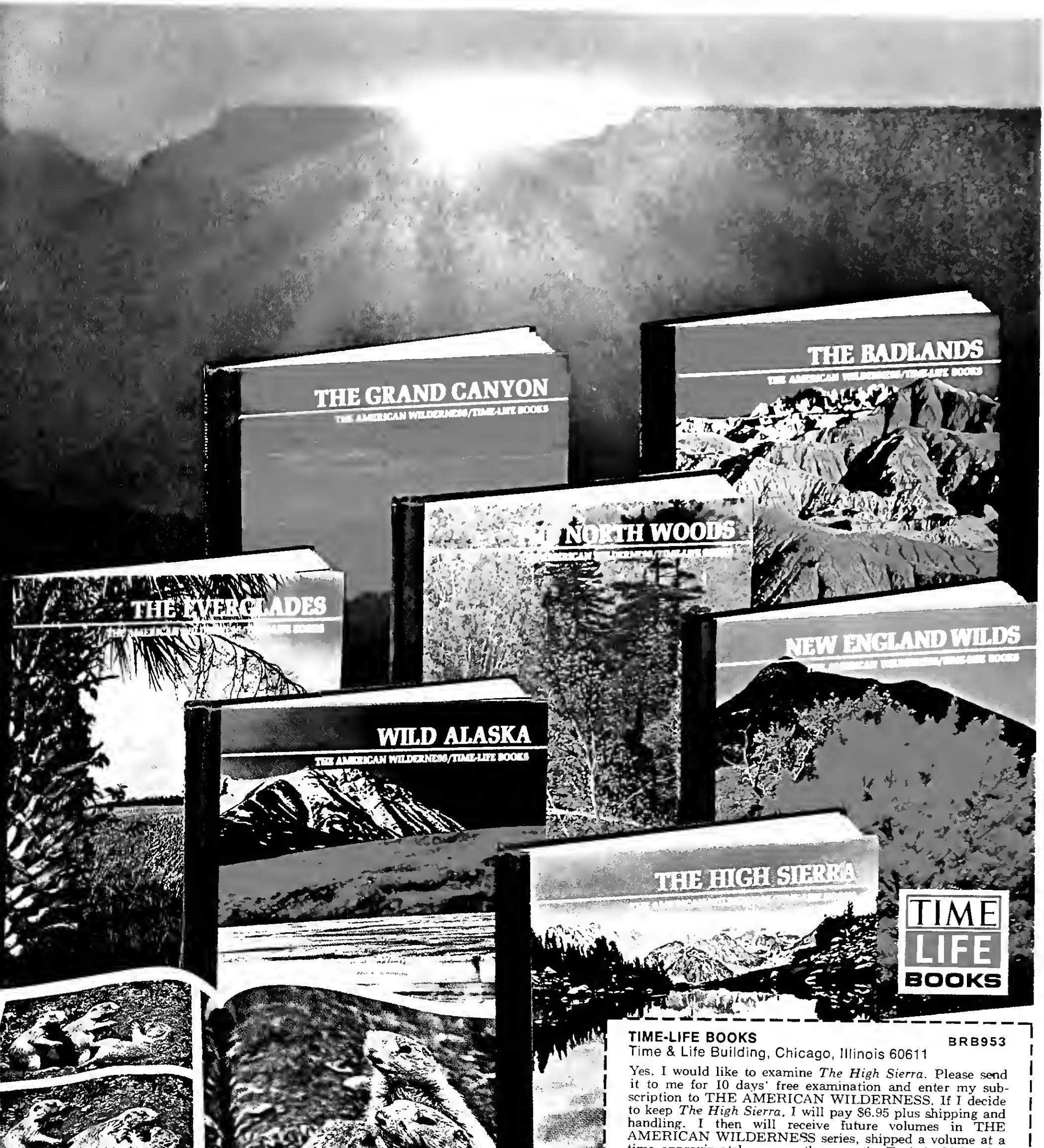
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Spirits of the Makassae

by Shepard Forman

The vengeful dead hasten an anthropologist's departure

The Makassae, like many other inhabitants of the Lesser Sunda Islands of Indonesia, invoke a strict taboo against naming the dead except in ritual contexts. This was made clear to me shortly after I began my fifteen months of field work in Portuguese Timor. For many of those months I applied myself to the difficult task of mastering the Makassae language, observing day-to-day activities in the preparation of gardens and rice paddies, and collecting kinship terminologies for living kinsmen.

Yet the dead were all around us, buried in prominent gravesites at the ancestral hearths and invoked as the spirit causes of most contretemps. Then, too, I was often invited to witness Makassae rituals, where I was encouraged to tape-record the incantations and the names of the spirits as each was called upon to receive his share of a sacrificial pig, water buffalo, chicken, or sacred rice.

The content of these ceremonies piqued my anthropological curiosity, and I longed to know the relationship between the living and the dead. My language teacher and cicerone, Nanai'e Nau Naha—a venerable old man who was "guardian of the myths and traditions" for the *suku,* or political domain, in which my family and I lived and worked—teased me with allusions to the links between the spirits and his living kinsmen. He offered his hints with a knowing smile that only whetted my appetite for the unknown. But in this case, it was also unknowable, I thought. For ethical reasons, and mindful of Makassae traditions, I refrained from asking the hundreds of questions that buzzed in my head and from the customary taking of genealogies.

Occasionally, I even had to remind Nanai'e of the taboo. Once, for example, he began to explain to me his relationship as the closest descendant of a one-time wife-giver to the lineage of a dead man to whose funeral he had been called. Whether he had actually intended to name names or not is a moot point. At the time, he commended me for my appreciation of the ways of the Makassae and jokingly told me that one day he might make me his apprentice.

Nearly eight months after we had settled in Makassae territory, high in the Mate Bian mountain range "where the spirits dance," Nanai'e told me that he wanted me to learn fully and correctly the ways of his people. He said that he and the other elders wanted to teach me and that he would start by giving me genealogies and clan histories so that I could begin to understand what it meant to be a Makassae. This occurred just after my family and I had returned from a month's stay in Australia. Upon their return to the field, anthropologists are often greeted as long-lost friends or at least as objects of greater trust. Somehow, coming back stands as testimony to one's commitment.

Aware of this, and of the peculiarities of our relationship to a subject people who have undergone centuries of colonial domination, I again cautioned Nanai'e about the breaking of taboos in our behalf. He responded that he had already consulted the lineage elders in the *suku* and that they all agreed that he should be my instructor. At the proper time, he said, the names would be secreted again in a special ceremony at Turanaba'a, the mythical origin site of the Makassae, where I would be asked to sacrifice a ram to Moon-Sun and his descendant spirits.

Two weeks later, my lessons began. Nanai'e recited the origin myth, in which a rock wren appeared from the top of Mate Bian, kicking back the floodwaters that covered the land so forcefully that it broke its leg and was transformed into a rock. The wren-turned-to-rock—now moss covered and sacred—stands in the hollow of a giant banyan tree that grows on the side of the abutment on which Turanaba'a is built. Nanai'e recounted the birth of the founders of the original Makassae clans from hermaphroditic ancestors, themselves

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spewn forth from the mountaintop. The son of Moon-Sun appeared first and was reborn as brother and sister who cohabited and produced an offspring who was again reborn as brother and sister. Their youngest son was given to the childless founder of Ka'o Si, Nanai'e's own house of origin. Beginning in this way with his own agnatic lineage, he then carefully reconstructed his genealogical ties to other lineages through ancestors who moved down the mountainside with their immediate kinsmen in a process of fissioning that gave rise to the present clusters of Makassae descent groups.

When Nanai'e did not know a particular sequence of events, he called in another lineage elder to check the details. He also asked the "guardians of the myths and traditions" from other lineage groupings in other *sukus* to tell me their own origin myths. The cosmological universe became flooded with names of sacred sites; with accounts of warfare between a female moon and a male sun, the defeat of the moon by fire, and the domestication of the cock; and with tales of ancestors ascending to the sky on areca palms and siring children who descended to earth through the seven vulvas of a particular configuration of stars. I was instructed in the Makassae paradigm of life—the generation of the crops by father sky and mother earth—and its relationship to the reproduction of human life, now symbolized in gifts and countergifts of bridewealth and dowry payments. I was invited to witness the sowing of the sacred rice as a prelude to the most important of Makassae rituals, "the making of the dead," in which the soul of the deceased is finally dispatched to Mate Bian where it will live forever among the ancestral spirits.

Field work was suddenly an anthropologist's dream. For nearly two months, people came to our house site daily and offered to record their versions of the myths or to comment on those given to me by others. Men and women sat on the veranda and laughingly told about the sexual component of their house-building ceremonies, about their marriage exchanges and mortuary rituals. The pace was fast, the work fun and intriguing, and my notebooks were filling up with extraordinary data. Each night I would review my notes or listen to a tape recording.

Each morning, Nanai'e, leaning heavily on his staff, would hobble down the mountain path that connected his house site with ours, and I would confront him with the many questions I was just beginning to formulate. He seemed to delight in the process of my learning. One night after a funeral, he led me down to a freshly covered grave to perform a ritual that had previously only been done in private, joking to his clansmen that I had indeed become his apprentice. He also urged me to write down everything in Makassae, as well as in English, so that his children would never forget the ways of their people.

One morning, just after I had mastered the complexities of a particular exchange relationship between a dead man's kin, Nanai'e suddenly foreclosed. He said I had learned as much as I needed to know and told me to acquire a ram "whose horns turned twice" and to bring it to Turanaba'a for sacrifice on the following Thursday morning. I was disheartened. Although I felt I needed to know much more, I was now under constraint not to ask. Still, I sent one of the gardeners who worked for me in search of a ram and while awaiting the special name-secreting ceremony, satis-

fied myself with constructing a questionnaire on social life and economics. Nanai'e helped willingly.

On Thursday morning at the crack of dawn, I set out with the gardener and the ram for Turanaba'a, the origin site where the sacrifice was to take place. For more than an hour we climbed up the steep mountain paths, passing several lineage compounds enclosed by palms and banana trees. Ultimately, we climbed through a thick grove to what, at first, seemed an impenetrable abutment on which ten houses were perched. Constructed of wood and thatch high up on wooden piles, they appeared to blend earthen color into the dusty ground. In contrast to other ancestral hearths I had visited, Turanaba'a was stark and barren, an excavated hilltop on which nothing grew. The bleakness was broken only by several stunning rock formations and, on the far side, the crown of the sacred banyan tree growing about fifty feet down on the hillside below.

Closest to the edge of the flattened abutment, and connected by a treacherous path to the tree in whose hollow the wren-turned-to-rock now sits, was the sacred house of Moon-Sun. Unpretentious in itself and not readily distinguishable from the house of any other ancestor, this most sacred of all Makassae places was the locus of tremendous activity. Two huge stones, the table and chair of Moon-Sun, served as an altar, laid out with a large palm leaf, a sacred sword, and several small woven baskets containing cooked rice and meat and small quantities of betelchew, which would be used to call the spirits.

Next to the altar, on an enormous stone grave, sat Nanai'e with two other elders. He beckoned me with a wave of his hand, and I walked slowly toward him, past a clutch of women who squatted at the outskirts of the site, anticipating a ceremony from which they were ritually excluded.

Arriving at the grave site, I was greeted with the now-familiar *hau mi'i*, a common Makassae salutation that simply means "come sit with us." I did—in the open place nearest to me. Nanai'e at once looked scornful, and Koo Rubi, the ritual specialist of Turanaba'a, a shy and restrained man who had always greeted me with caution, now shouted at me to get up. I jumped to my feet, apologizing and at the same time asking what I had done. "We cannot tell you," Koo Rubi said. "The names have been secreted again." I had obviously done something very wrong (I later learned that I had sat on the headstone of Moon-Sun's son, ostensibly the first of the Makassae ancestors), but the occurrence seemed to be immediately forgotten. The three elders shifted their places somewhat, and I sat elsewhere on the same grave site. We talked for a while, mainly small talk about life in America and the poverty of Timor. Koo Rubi called the spirits with offerings of meat, rice, and betelchew, and Nanai'e asked me to tape the following special chant in which they called on the ancestors to forgive us for speaking their names and recounted the reasons for having done so.

> This stranger came and we were obliged to speak your names so that he could write them in his notes and books. I told this American, "Ours are sacred. We cannot speak them idly. After speaking them we must secrete them again. We must make them sacred again." Therefore, this American bought this ram and brought it here to our hearth to speak your name. Now we will put your name in its

place again and we will put your word in its place again. Your name is sacred again, and also your person.

The rams were slaughtered, along with ten chickens, each of which was quietly suffocated in the name of a lineage founder whose genealogy I had been given. While the meat was being slaughtered and cooked and the entrails divined, I was invited to see the sacred banyan tree and the wren-turned-to-rock in its hollow.

Few Makassae have descended the path to where the forbidden tree and rock stand. I was the first stranger to do so. In the circumstance, it was an awesome sight, and the power and mystery of their beliefs took on new meaning for me. I asked if I could take some photographs while Koo Rubi recited the origin myth and made an offering at the site. He agreed, but insisted I use film for slides. (I had previously explained a critical difference between black-and-white film and slides. Black-and-white film could be developed locally, and I frequently gave out prints to those I had photographed. Slides, on the other hand, only projected an image and could not be possessed. Koo Rubi obviously preferred that I photograph the rock and tree in slides, lest anyone possess their most sacred object.)

Having viewed the rock and tree, the solemnities over, we climbed back up to the clearing where an enormous feast was laid out. Nanai'e, Koo Rubi, and the third elder ate at the altar, and I sat nearby on the ground with two "lords of the land," secular chiefs who had joined the party. The men of the lineage sat between us, devouring the meat and guzzling *ma buti*, the wine of the sago palm. The "lords" and I drank *ma sabu*, a distilled version that is far more potent, and talked and joked until the sun dipped behind the hills to the west. We parted with the warmest of Makassae leave-takings, two-handed clasps all around, my gaffe seemingly forgotten.

For two weeks thereafter, I concentrated (with Nanai'e's help) on filling out the questionnaires we had prepared. People volunteered to submit to my two and a half hours of questioning, and I completed nearly twenty forms, which provided me with considerable sociological and economic information. My family and I were confident in our relationships with the Makassae and comfortable in the setting we had made for ourselves.

Then one Saturday afternoon, as my wife nursed a cold in bed and the children played on the veranda, I entered the main room of our palm-frond house and spotted an object curled around my sweater. I reached for the sweater, but quickly withdrew. A pit viper! It was the most deadly snake in the region, and the Makassae have a developed folklore about it. They believe it lives in trees, hurling itself against horses and cattle and invariably blinding them. A man dare not go near one, for its bite will kill in twenty-four hours.

"Cobra!" I shouted, as the Makassae word completely eluded me. It dropped to the floor and slithered quickly away from me as I ran toward the door on the opposite wall. "Snake!" I yelled to my children, who fled the veranda lest the dreaded viper exit through a space in the loosely joined wall. One of the gardeners and some of the household staff came running to the house, where the snake was now curled around our shortwave radio on a table. *Baneleke!* they yelled, obviously sharing my excitement and fear. They asked me if they should kill this highly venomous creature. "Kill it, indeed," I ordered, and ten minutes later it was over, at least the heroics of it.

After the dead snake—dangling from the end of an extended dibble stick—had been removed, people began gathering at the house. They entered into animated conversation about the snake, its character and behavior. One thing they agreed upon: it was unheard of that the snake should appear in a house. One young man ventured that it was a *kina,* or sign, an omen that someone had it in for us and had planted poison around our house. Once stepped upon, the poison would take effect, killing us in an indeterminate amount of time. "Some poisons take weeks. Others months. Others years. You never know." He left quickly, promising to send his uncle to perform the appropriate countermagic. He never came.

In the meantime, Anu Loi, one of our gardeners, returned from the rice market, arriving just as the snake was being buried in a small clearing near our garden. "You killed it!" he pronounced, obviously troubled by what

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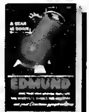

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we had done. He immediately sat down on our veranda and began to divine. Putting the index finger and thumb of his left hand together, he placed them on his right wrist, then slid his extended thumb along his forearm and drew up his index finger until it touched the thumb. When the fingers touched, he muttered the name of a spirit or an enemy. He repeated these steps as he moved his fingers slowly up toward his shoulder. He then started back down his arm until his thumb and index finger finally reached the crook of his elbow. There he stopped. The name he spoke was Turanaba'a.

The snake was a messenger from the people of the origin site, Anu Loi explained. It was sent to remind me of my error when I sat on Moon-Sun's son's gravestone and to urge me to make another sacrifice, this time of a pig. Not wanting to act precipitously, I sent for Nanai'e, who didn't arrive for several hours. He consulted our staff and huddled with the diviner. Eventually, he concurred. The snake was a messenger from Turanaba'a. It had entered our house as an ant, and once inside, it took on the appearance of a snake. Instead of killing it, we should have called for a charmer who would have lured it out of the house with sweet rice. Then it would have returned to Turanaba'a of its own volition. It meant us no harm. A new sacrifice was in order, but we would have to wait until Koo Rubi told us the time was right.

Nanai'e sent for Koo Rubi, who arrived one hour later. He, too, deliberated with everyone there. Anu Loi's reasoning was correct, he announced, but we could not act until we had another sign. "Wait," Koo Rubi told us, "another snake will come to affirm the message."

We hardly slept that night and woke the next morning with considerable trepidation, knowing that we would have to face an inquiring populace at the Sunday market. At about 9:00 A.M., we left our house and started up the path to the marketplace. Suddenly, a woman began to wail and, dropping her basket of tubers, ran past us toward the mountain. Men and women alike began to drop the produce they carried on their shoulders and heads and turned to run back along the path toward their homes. We turned and stood watching, speechless. At the top of the abutment behind our house, flames were leaping upward from the thatch roof of a house. Within minutes the entire hillock was ablaze. A strong wind came up off Mate Bian and carried the flames to Sai Oma, Nanai'e's own lineage house, and from there to Bui Lo, and on through a thicket of bamboo to Olale, finally engulfing Turanaba'a and the house of Moon-Sun itself.

In the dryness of the intermonsoon, the fire spread quickly, and before the first man could reach it, the entire origin site, two additional ancestral hearths, and twenty-one lineage houses had been completely destroyed. In the pathetic recounting that later took place, more than a hundred families told of losing their most important possessions.

Anu Loi lost everything but one pair of shorts and a store-bought cloth. Our goatherd, Koo Laka, also lost everything he owned, save his unharvested rice. Saba Loi, whose ninety sacks of rice were burned, appeared that afternoon at the cockfights in a loin cloth so that everyone could see that he was left with nothing. His eyes were red from smoke and from private tears.

While three major fires had occurred in Turanaba'a in living memory, this was by far the worst. Blame had to be set, so a divination was announced for dawn of the following morning. The immediate cause of the fire was known to everyone. Sahe Raku, a distant kinswoman of Nanai'e, had left her cooking fire burning when she went to market, and a gust of wind from the mountain carried a spark to the roof of her house. But efficient cause is not sufficient cause for the Makassae, and a divination was necessary to know why the fire had to occur at all and which ancestor had to be placated so that it would not occur again. Nanai'e, who had suffered among the greatest losses in the conflagration, insisted that I attend.

Well before dawn the next morning, I began the climb back up to Turanaba'a where the divination was to take place. I arrived in time to see Nanai'e laying out a circle of stones, measured equidistantly with a cord from a sacred spear placed in the ground at its center. He walked around the circle, pointing to each of the stones in turn and designating them as ancestor spirit or enemy who might have had cause to provoke the disastrous fire.

One of the stones in the circle was named for the founder of Sahe Raku's house, where the fire began and which was said to have been in need of roof repair. Another was named for Sahe Raku's son, who had been accused of stealing rice from his mother's brother and had been ordered to make amends by slaughtering a pig, but never did. I waited somewhat anxiously while twenty-six stones were named in all, and was relieved that none bore my name or Nanai'e's or, as far as I could discern, the names of any of the important ancestors who had figured in my lessons.

Then, just as the first rays of sunlight fell on the circle of stones, a young rooster that had not yet sung was hand-fed a few grains of sacred rice and held up to the fading moon and the rising sun. The end of the cord that extended from the spear was looped around one foot. *Nai suma!* ("choose a name!") he was told, and with a sudden gesture his head was severed from his body and he was left to writhe in the circle of stones until he died atop the telltale one or in the center, which marked the area of Moon-Sun's will.

In a moment, it was over. The young cock died astride the two rocks named for Sahe Raku's unrepaired house and for her son. While clusters of men and women began to debate whether or not to chastise her and how, Nanai'e looked at me, smiled wanly, and winked. Later, I asked him about that wink and about his failure to name a stone that might be associated either with our lessons or with my sitting gaffe. "I know how that would have come out," he said solemnly, "and I could not bear the responsibility."

The implications of my responsibility were, nonetheless, on everyone's mind, and thereafter field work became a heavy burden. People were polite, as always, but our areas of mutual concern turned away from ritual and belief and back to planting and technology. No more questionnaires were completed. When the first house post was set for the rebuilding of one of the burned-out lineage houses, I was conspicuously not invited; instead, the villagers sent me a loin of pork, the usual gift to an outsider of authority. The names had been secreted once again, as had the persons. My wife and I planned our withdrawal and took leave of the Makassae soon after, the smoldering embers of the fire in the hearth seared forever in our memories. □

Drift Coconuts

On the beach with a field researcher—who must fight off rats, pigs, and his own cultural load to get the data

Seventy-five yards from the beach, just at the edge of the first surf break, an almost submerged coconut bobs and rolls in the water. Borne by the currents and winds of the Caribbean, it has drifted from an unknown source until by chance it has arrived offshore of the Miskito Indian village of Tasbapauni in Nicaragua. The coconut is a self-contained, long-distance drifter. An impervious green skin shields it from marine elements; its thick, fibrous husk gives buoyancy; and its well-protected seed can retain germination powers for months.

Closer to the beach, a large swell catches the coconut, sucking it into the water wall as the wave form builds and breaks and sends the husked flotsam into foam-speckled shallow waters. Each breaking wave carries the coconut a little closer to shore. Stranded partway up the beach by the ebbing tide, it glistens and dries in the tropical sun. That night, a full-moon spring tide and a heavy wind-generated surf carry the drift coconut high onto the debris-strewn beach, beyond the limit of normal wave reach. It has finally come to rest on the eastern shore of Nicaragua after an uncharted journey.

Lodged in loose sand at the edge of wind-sheared coco plum and sea grape thickets, long trailing runners of beach morning glories, and strand-line rows of domesticated coconut palms, the sea-fresh pioneer is tenuously established in its new environment. Days of wind, rain, and hot sun pass, and the young green colors fade and weather to earth brown.

Some four months after falling and drifting from its parent tree, the coconut's dark brown, desiccated husk may send forth a leafy shoot, while its roots continue to grow inside. If undisturbed, the roots will eventually break through and start to anchor the palm to its new site.

But the morning after a strong storm, the drift coconut has disappeared from the beach. Damp sand and flotsam mark where storm waves undercut the beach berm, scalloping cutouts in the margins of strand-line vegetation. Carried out to sea again before it could be anchored, the drift coconut may soon be washed up on another shore by tides, winds, and currents. Its brief spell on this beach left no marks or indications that it ever passed this way.

In the Miskito language, a drift coconut is called *kuku awra*, a term that also is used to refer to any foreigner who has come to their shores. Vagabonds, transient visitors, culturally and economically displaced persons are all *kuku awra* to the Miskito. They suddenly appear from unknown places, transported by chance and strange fates to lodge with the Miskito. Most stay but a short time before drifting to another place. Yet these *kuku awra* leave a wake, a trail, and memories. And even though only briefly established on Miskito shores, they take with them something too.

Since 1968, I have made several research trips to eastern Nicaragua. Along with my wife, son, and an occasional graduate student, I have studied the Miskito subsistence economy: how it was, how it is changing, and consequent impacts on social and economic relationships; agricultural, hunting, and fishing productivity; diet and nutrition; use of resources and impact on fauna and flora; and how economic inflation and out-migration have affected village livelihood. We have also spent a good deal of time studying sea turtles: their behavior, ecology, and exploitation. In turn, the Miskito have studied us and drawn their own conclusions—thankfully still unpublished.

It takes a lot to surprise the Miskito, but then we often did a lot of surprising things. Equipped with scales of various shapes and sizes, we weighed food crops, food in the pot, and food just before it went into their mouths. It's amazing that they put up with us. With tables and chemicals, we analyzed water, food, and soil samples. We caught or purchased what, to the Miskito, were valuable sea turtles; weighed, measured, and tagged them; then let them go. We brought big aluminum cases filled with gear: still cameras, underwater cameras, 16mm cameras, and videotape cameras. Things were weighed, photographed, categorized, and filed. Questioners gave questionnaires to questionees on household budgets and composition, births, deaths, social relationships, and the like. Back home, copious field notes were cross-indexed, tabulated, keypunched, and fed into computers. Significant relationships were analyzed and conclusions drawn. But much of what I learned isn't contained in the books and papers that resulted from this research. For the first time, I'm going to try to tell how it really was.

The first Miskito Indian I talked to was about 45 years old and had been eyeing me curiously as I walked up the trail to his village. The little diesel boat that brought me had pulled away from the landing and chugged off across the lagoon. I gathered up my belongings and cautiously navigated my way along the muddy path. Sitting on the porch of the first house in the village, legs swinging back and forth, the man watched my every move and, embarrassingly, every slip I made in the mud. I was apprehensive about meeting the Miskito and wanted the first encounter to be socially correct. I wanted to explain to someone in authority, a respected leader in the village, why I had come to this particular village.

"How is it," I asked him, using the Creole phrase for "hello."

"Right here," he answered, impassively.

"That's good. Tell me, where can I find the oldest man in the village?"

"Oldest man? Oldest man? Oldest man, him dead!"

I cherish that moment. It was one of the many philosophical rewards of living with the Miskito. I wrote about that encounter some years ago, but I didn't learn until later that the Miskito of Tasbapauni had also recorded that first meeting as part of their own verbal chronicles.

I ran into my First Miskito on a

by Bernard Nietschmann

subsequent trip. "So you come again, Mr. Barney."

"That's right. How is it this time, Mr. Clemente?"

"Fine. Right here, same as always, life spare. You still looking for the oldest man?"

Studying the particular topic at hand is the easiest part of doing field research. What is difficult is to reorient your cultural load, establish some sort of perceivable role, and maintain body, mind, and equipment. It is impossible to prepare for the many cultural, philosophical, and psychological challenges to your preconceived notions of doing field work. One must cope with frequent frustrations, blind alleys, misgivings, disenchantments, boredom, startling contradictions, and unexpected setbacks. Nor can one prepare adequately for the specific problems that will be encountered: how to deal with a situation in which a person who you thought was your "good friend," the personification and embodiment of the "noble savage," is really cultivating an economic relationship aimed at acquiring the watch your parents gave you for graduation; how to maintain and repair light meters, cameras, typewriters, and the additional discipline-related mechanical contrivances upon which your research depends, but whose reliability factor is nil beyond the place of purchase; or how to live in a fishbowl where privacy doesn't exist; where your every act, mistake, and relationship are immediately known by all, and strange explanations for what you are really up to are manufactured and disseminated with great imagination and speed.

Providing for cooked food, transportation, good health, and occasional private moments are the most time-consuming and frustrating problems involved in field research. But one quickly learns to adapt and cope and persevere. There are other things more bothersome.

Living in the rainy humid tropics and right next to the sea brings with it a host of small-scale challenges. You soon discover that you have been raising secret zoos and gardens. All

leather materials quickly begin to sprout greenish fungal patches, and cockroaches delight in living in, and dining on, the insides of radios and tape recorders. Books start bowing and ballooning in the high humidity, writing paper takes on the structural rigidity of a wet dishcloth, envelopes self-seal, hinges rust and separate, cameras turn into expensive paperweights, and clothes are always damp and mildewed.

During most of the year, too much water is the problem, while the opposite is true during the short dry season. Then the wells run dry and available water has to be carefully and judiciously used. For example, I learned how to do the following with the same three cups of water: brush teeth, wash hair, sponge bathe, and shave. There is a secret to this, involving split-second timing, taking out a cup of water at one stage and adding it later, and great restraint not to look at the water. These are but insignificant nuisances. They give character to a place and make every day a little bit more interesting. I often think I miss them.

There were two things I will never miss. I didn't cope with them too well nor did I ever adapt to them. I believe that much of my inability to become accustomed to them results from strong childhood impressions left from reading about the rat torture in Orwell's *1984* and learning how pigs ran things in his *Animal Farm.*

Every house in Tasbapauni has a few rats living in its thatch roof; in the thick palm fronds, they burrow, cut tunnels, raise families, and do other rat things. During the day, they are usually quiet, confining themselves to the safety of their elevated perches. Nighttime is another thing entirely. They scurry about—apparently playing tag—squeak, search for food, and generally take over the house. Every so often, enthusiasm exceeds ability and they slip off one of the narrow poles that cross-brace the roof. This is why I don't like rats.

The second night I spent in a Miskito village coincided, unfortunately, with the "rat Olympics" being held directly overhead. I listened to their activities for a while, but fell asleep partway through the jousting event, in which two rats at opposite ends of a rafter pole run headlong at each other. A sudden heavy thump on my chest awakened me, and I looked down to see a groggy three- or four-pound rat clenching my T-shirt, staring back, whiskers at my neck, heartbeat racing in its warm rodent body. Dazed and frightened, it held desperately to the cotton cloth, resisting my efforts to roll it off. I couldn't take the T-shirt off, and, envisioning a death lunge at my throat, I took the only alternative left: panic—sheer, unadulterated, glorious, screamy panic. The rat departed.

The room I slept in was only seventy-five yards or so from the beach, and the sea breeze was strong enough to keep mosquitoes away, so there was no need to sleep under a net. Nevertheless, I did from then on, just to keep the rats off. Every so often, a rat would fall, hit the net, and scamper down the sides. It happened often enough that I began to wonder what was happening in other houses. I decided to do a study.

A house-to-house survey revealed that although there were plenty of rats, they seldom fell. I began to feel singled out. Perhaps the rats enjoyed the trampoline I'd put up for them.

Various people told me that they had noticed an increase in the number of rats. They complained that some of their cats died after each visit by the SNEM malaria personnel (Servicio Nacional de la Erradicación de Malaria) and the spraying of houses with a solution of DDT, water, and kerosene. Cats are notoriously sensitive to DDT; in their constant preening they had probably ingested small but deadly amounts of the insecticide picked up from around the house. Fewer mosquitoes and less malaria also meant fewer cats and more rats.

Several weeks later, I went to clean out the rain barrel we'd been using for drinking water, only to discover a complete rat skeleton at the bottom.

I started to take a definite dislike toward rats. I sent away for large spring traps and passed them out to all who wanted to reduce their household rat population. I experimented with various baits and found that the best was guava jelly. Some Miskito remember me only from those spring traps and guava jelly. My first tangible role in the village was as a rat exterminator.

The antirat campaign was fairly effective, enough so that one Miskito family got mad at me. From their point of view, it was a case of "just when you really need a rat, you can't find it"; and they couldn't find a rat because of me. The reason they

An American Portrait 2076.

Several months ago we started our Tricentennial Program by asking for your thoughts on life in America by the year 2076. Instead of a lot of ideas about space ships and robots of the future most of the more than 50,000 responses we've received have been about people's visions of our future as a nation.

The main point that came through, letter after letter, was that most people believe a lot of the things that made America what it is today will shape our future as well.

An overwhelming number of you — ninety-one percent — told us you want the family to remain our basic social unit.

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wanted a rat was because one of their children had whooping cough, and rat soup was a sure-fire cure for it. I tended to disagree, but they would have none of it. They wanted a rat. A live one. I checked my rat-frequency map of village houses and suggested they try a particular house not far from theirs.

All furniture was taken out and placed on the grass outside. A platoon of young children armed with sticks and brooms came into the house. The mother and father of the sick child then began to beat and poke the thatch roof with long poles, driving the rats from their lairs, down the walls, to confront the gantlet of child-held, poised sticks. After a great deal of running about, everyone yelling instructions, children colliding with each other, and near misses, a rat was finally cornered, dispatched, and handed to the grateful father.

To make rat soup, you need a freshly killed rat. The first step is to singe the hair in a wood fire and then scrape the remaining charred hair from the body with a dull knife. Next, place the rat at the edge of the fire, but not in it. Slowly turn the rat until a clear oil begins to collect on the skin. Scrape this off and save (you'll get about one half to one teaspoon from the average-sized rat). Now the carcass can be eviscerated, cleaned, and chopped into one-inch pieces. Place the meat into a pot of boiling water over a medium heat and cook until it's reduced to a thick soup. Before serving, float a few drops of the rat oil on top of each portion. Later the parents told me that the soup worked; the child recovered from their diagnosed whooping cough.

Pigs posed a more personal problem for me. There were many pigs in the village; young ones that ran in packs, and large ones, 100 to 175 pounds, that sometimes roamed by themselves and other times grouped together for safety and cooperative ventures. Few of the pigs were penned despite the complaints of non-pig owners; pigs simply eat too much for a family to supply all their food. Instead, they are allowed to roam at will, feeding on whatever they can find. They are free-foraging, self-maintaining bank accounts. The Miskito keep pigs not to eat, but to sell.

A full-grown pig is a valuable animal. Buyers from Bluefields, a small city down the coast, often come to "look pig," and a big specimen can be sold for as much as $50. A Miskito

Annually, delegates from America's nearly 1,000 rural electric cooperatives and public power districts which serve some 25 million people across the nation, meet to formulate and adopt policies on national issues.

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America's rural electric systems

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is quick to sell a pig for money but won't eat it even in times of severe meat scarcity. This is because a pig is worth too much money to eat and because they are rather indiscriminate foragers. To the Miskito, a pig is not only a dirty animal but its meat is also considered unclean. When they sell a pig to a Spanish-speaking buyer, they are happy to get the money, but may grin and wink a bit more than would be expected over just another economic transaction. That's because they know the pig's feeding history and its ultimate fate: the restaurants and family tables of what they consider unsuspecting Bluefields folk.

I was quickly repulsed by pig dining habits. There were only three outhouses in the village, all built under the direction of different missionaries for the "mission houses" where they stayed during visits. As visitors we were offered the use of one of the nearby outhouses. For this we were grateful, as one of the most difficult things that we were trying to adapt to was the nocturnal scheduling of Miskito toilet habits. Ready access to an available toilet is so common in our society that we were quite unprepared for a different waste regimen among the Miskito. One went at night, either on the beach or in the bushes. If mischance should befall you during the day, it was a long and exposed walk to the bushes. That's why we were happy for access to the outhouse, which served as an emergency safety valve during our time of readaptation.

It was because of the outhouse that I became interested in pigs. The outhouse was about twenty-five yards from where we were staying. Built in the ubiquitous style, it stood on wood pilings some two feet off the ground. This elevation, I soon discovered, offered protection from more than just the wet ground of the rainy season.

What was, at first, a disagreeable discovery soon became a testable hypothesis: pigs can tell the difference in your intent before you reach the outhouse. For the sake of the more puritanical readers, I will use the common euphemisms to illustrate this: number one (N1) and number two (N2). If our intent was N1, the roaming pigs displayed no interest. However, if it was N2, they came running. They seemed to be able to tell within five or ten yards of our walk to the outhouse. And pigs are fast; they'd beat us there, crawl under, and be waiting. Some would stand on their hind legs, snouts thrust

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through the wooden hole. That was a bit disconcerting. Somehow they were able to decipher our body language. I began to try to fake them out. I imitated what I thought was a good N2 walk, when it was really an N1 mission. Nothing. Oh, perhaps a grunt or two from one of the larger pigs and a half-hearted trot from a young one, but nothing of any consequence. Try as I might, they never fell for a fake walk. Unerringly, they knew the difference.

To cope with their amazing discriminatory ability, each of us devised different defensive strategies. I made a club, a "pig stick," 1½ inches in diameter and 2½ feet long. With this, I could strike from within the outhouse and inflict enough damage to discourage pig congregations for periods of up to five minutes, especially if accompanied by my loud imitations of aggressive pig sounds. My wife, Judi, hit on an alternative strategy. She posted me outside the outhouse as "pig guard." I'd go ahead carrying the pig stick and signal when the field was clear. It was my job to keep the pigs at bay. Our son probably coped with the situation best. He fancied himself a bombardier and enacted modern versions of "Thirty Seconds Over Tasbapauni."

I finally decided to follow the pigs in retaliation; all in the name of ecology, of course. Anything is grist for the inquisitive mind. I took notice of their group behavior and dynamics, home and foraging ranges, and territoriality. The thing that interested me most was their foraging patterns and range. During the day, the pigs concentrated on the village itself, making sweeps in small bands around every back kitchen, where refuse and vegetable wastes were thrown at fairly predictable times. Their only competitors for this food supply were chickens. Pigs fared poorly, however, when competing with dogs for waste from butcherings of turtles, deer, and other wild animals. The dogs took the best, and the rest was up for grabs between turkey vultures and pigs.

The periphery of the village was one of the most important foraging zones for pigs. Surrounded on three sides by bush-rimmed forest and on the other by the beach, the village edges were used by the Miskito as nocturnal dumping sites. Pigs patrolled these areas at dusk, two or three times during the night, and in

early morning. During these times, most of the pigs continually circled the village, around and around on the Tasbapauni Beltway.

Pigs make the major contribution in keeping the village clean, but turkey vultures, dogs, and chickens also help; consequently, waste materials do not last long on the ground. There are no waste disposal problems in the village. All organic debris are recycled. The Miskito have no problem with cans, bottles, papers, and the like because they are rarely used—and seldom thrown away. My still unpublished research study came to the conclusion that pigs were the most important consumers in the detritus chain. The pigs were obviously effective garbage engineers, providing a valuable service for the villagers, one that was ecologically and economically sound. They made day and night pickups, didn't belong to a union, never went on strike, were extremely efficient, and could be sold before retirement age.

After many such field trips to the Miskito villages strung along the eastern coast of Nicaragua, I came to know something of the people and to appreciate their life-styles. Coming from an academic background, where many of my colleagues write about native women breaking rocks with wet clothes, I found that it was necessary to reevaluate my first impressions of the Miskito—and their pigs and rats.

The etchings of our scientific incursions are probably as indelible to the Miskito as they are to us. They investigated us, as we did them—each trying to figure out what was really behind the other's strange behavior. There is a lot of interest in a *kuku awra* who weighs carefully what is abundant, writes detailed notes on what everyone else considers obvious, has a rat fetish, and follows pigs around. The undecipherable visits of such a character will eventually be fitted into some logical local context. For this drift coconut, the memories of landing on those shores remain perfectly clear and the lessons learned have proved useful on excursions to other parts of the world as well as at home.

Bernard Nietschmann, associate professor of geography at the University of Michigan, is currently working out of Australian National University as a senior research fellow.

So Cleverly Kind an Animal

Basic human kindness may be as "animal" as human nastiness

In *Civilization and Its Discontents,* Sigmund Freud examined the agonizing dilemma of human social life. We are by nature selfish and aggressive, yet any successful civilization demands that we suppress our biological inclinations and act altruistically for common good and harmony. Freud argued further that as civilizations become increasingly complex and "modern," we must renounce more and more of our innate selves. This we do imperfectly, with guilt, pain, and hardship; the price of civilization is individual suffering.

> It is impossible to overlook the extent to which civilization is built up upon a renunciation of instinct, how much it presupposes precisely the non-satisfaction . . . of powerful instincts. This "cultural frustration" dominates the large field of social relationships between human beings.

Freud's argument is a particularly forceful variation on a ubiquitous theme in speculations about "human nature." What we criticize in ourselves, we attribute to our animal past. Brutality, aggression, selfishness—in short, general nastiness—are the shackles of our apish ancestry. We strive (with pitifully limited success) for a better future based on reason and kindness—the mental transcendence of our biological limitations.

Little more than ancient prejudice supports this common belief. It certainly gains no justification from science—so profound is our ignorance about the biology of human behavior. It arises from such sources as the theology of the human soul and the "dualism" of philosophers who sought separate realms for mind and body. It has roots in an attitude that I have often attacked in this column: our desire to view the history of life as progressive and to place ourselves on top of the heap (with all the prerogatives of domination). We seek a criterion for our uniqueness, settle (naturally) upon our minds, and define the noble results of human consciousness as something intrinsically apart from biology. But why? Why should our nastiness be the baggage of an apish past and our kindness uniquely human? Why should we not seek continuity with other animals for our "noble" traits as well?

One nagging scientific argument does seem to support this ancient prejudice. The essential ingredient of human kindness is altruism—sacrifice of our personal comfort, even our lives in extreme cases, for the benefit of others. Yet, if we accept the Darwinian mechanism of evolution, how can altruism be part of biology? Natural selection dictates that organisms act in their own self-interest. They know nothing of such abstract concepts as "the good of the species." They "struggle" continuously to increase the representation of their genes at the expense of their fellows. And that, for all its baldness, is all there is to it; we have discovered no higher principle in nature. Individual advantage, Darwin argues, is the only criterion of success in nature. The harmony of life goes no deeper. The balance of nature arises from interaction between competing teams, each trying to win the prize for itself alone, not from the cooperative sharing of limited resources.

How, then, could anything but

selfishness ever evolve as a biological trait of behavior? If altruism is the cement of stable societies, then human society must be fundamentally outside nature. There is one way around this dilemma. Can an apparently altruistic act be "selfish" in this Darwinian sense? Can an individual's sacrifice ever lead to the perpetuation of his own genes? The answer to this seemingly contradictory proposition is "yes." We owe the resolution of this paradox to the theory of "kin selection" developed in the early 1960s by W.D. Hamilton, a British theoretical biologist. It has been stressed as the cornerstone for a biological theory of society in E.O. Wilson's *Sociobiology*. (I criticized the deterministic aspects of Wilson's speculations on human behavior in my May 1976 column. I also praised his general theory of altruism, and continue this theme now.)

The legacy of brilliant men includes undeveloped foresight. Eccentric English biologist J.B.S. Haldane probably anticipated every good idea that evolutionary theorists will invent during this century. Haldane, arguing about altruism one evening in a pub, reportedly made some quick calculations on the back of an envelope, and announced: "I will lay down my life for two brothers or eight cousins." What did Haldane mean by such a cryptic comment? Human chromosomes generally come in pairs: We receive one set from our mother's egg; the other from our father's sperm. Thus, we possess a paternal and a maternal copy of each gene. Take any human gene. What is the probability that a brother will share the same gene? Suppose that it is on a maternal chromosome (the argument works the same way for paternal chromosomes). Each egg cell contains one chromosome of each pair—that is, one half the mother's genes. The egg cell that made your brother either had the same chromosome you received or the other member of the pair. The chance that you share your brother's gene is an even fifty-fifty. Your brother shares half your genes and is, in the Darwinian calculus, the same as half of you.

Suppose, then, that you are walking down the road with three brothers. A monster approaches with clearly murderous intent. Your brothers do not see it. You have only two alternatives: Approach it and give a rousing Bronx cheer, thereby warning your brothers, who hide and escape, and insuring your own demise; or hide and watch the monster feast on your three brothers. What, as an accomplished player of the Darwinian game, should you do? The answer must be, step right up and cheer—for you have only yourself to lose, while your three brothers represent one and a half of you. Better that they should live to propagate 150 percent of your genes. Your apparently altruistic act is genetically "selfish," for it maximizes the contribution of your genes to the next generation.

According to the theory of kin selection, animals evolve behaviors that endanger or sacrifice themselves only if such altruistic acts increase their own genetic potential by benefiting kin. Altruism and the society of kin must go hand in hand; the benefits of kin selection may even propel the evolution of social interaction. While my absurd example of four brothers and a monster is simplistic, the situation becomes much more complex with twelfth cousins, four times removed. Hamilton's theory does not only belabor the obvious.

Hamilton's theory has had stun-

ning success in explaining some persistent biological puzzles in the evolution of social behavior in the Hymenoptera—ants, bees, and wasps. Why has true sociality evolved independently at least eleven times in the Hymenoptera and only once among other insects (the termites)? Why are sterile worker castes always female in the Hymenoptera, but both male and female in termites? The answers seem to lie in the workings of kin selection within the unusual genetic system of the Hymenoptera.

Most sexually reproducing animals are diploid; their cells contain two sets of chromosomes—one derived from their mother; the other from their father. Termites, like most insects, are diploid. The social Hymenoptera, on the other hand, are haplodiploid. Females develop from fertilized eggs as normal diploid individuals with maternal and paternal sets of chromosomes. But males develop from unfertilized eggs and possess only the maternal set of chromosomes; they are, in technical parlance, haploid (half the normal number of chromosomes).

In diploid organisms, genetic relationships of sibs and parents are symmetrical: parents share half their genes with their children, and each sib (on average) shares half its genes with any other sib, male or female. But in haplodiploid species, genetic relationships are asymmetrical, permitting kin selection to work in an unusual and potent way. Consider the relationship of a queen ant to her sons and daughters, and the relationship of these daughters to their sisters and brothers:

1. The queen is related by ½ to both her sons and daughters; each of her offspring carries ½ her chromosomes and, therefore, ½ her genes.

2. Sisters are related to their brothers, not by ½ as in diploid organisms, but only by ¼. Take any of a sister's genes. Chances are ½ that it is a paternal gene. If so, she cannot share it with her brother (who has no paternal genes). If it is a maternal gene, then chances are ½ that her brother has it as well. Her total relationship with her brother is the average of zero (for paternal genes) and ½ (for maternal genes), or ¼.

3. Sisters are related to their sisters by ¾. Again, take any gene. If it is paternal, then her sister must share it (since fathers have only one set of chromosomes to pass to all daughters). If it is maternal, then her

sister has a fifty-fifty chance of sharing it, as before. Sisters are related by the average of 1 (for paternal genes) and ½ (for maternal genes), or ¾.

These asymmetries seem to provide a simple and elegant explanation for that most altruistic of animal behaviors—the "willingness" of sterile female workers to forego their own reproduction in order to help their mothers raise more sisters. As long as a worker can invest preferentially in her sisters, she will perpetuate more of her genes by helping her mother raise fertile sisters (¾ relationship) than by raising fertile daughters herself (½ relationship). But a male has no inclination toward sterility and labor. He would much rather raise daughters, who share all his genes, than help sisters, who share only ½ of them. (I do not mean to attribute conscious will to creatures with such rudimentary brains. I use such phrases as "he would rather" only as a convenient shortcut for "in the course of evolution, males who did not behave this way have been placed at a selective disadvantage and gradually eliminated.")

My colleagues R.L. Trivers and H. Hare have recently reported the following important discovery in *Science* (January 23, 1976): They argue that queens and workers should prefer different sex ratios for fertile offspring. The queen favors a 1:1 ratio of males to females since she is equally related (by ½) to her sons and daughters. But the workers raise the offspring and can impose their preferences upon the queen by selective nurturing of her eggs. Workers would rather raise fertile sisters (relationship ¾) than brothers (relationship ¼). But they must raise some brothers, lest their sisters fail to find mates. So they compromise by favoring sisters to the extent of their stronger relationship to them. Since they are three times more related to sisters than brothers, they should invest three times more energy in raising sisters. Workers invest energy by feeding; the extent of feeding is reflected in the adult weight of fertile offspring. Trivers and Hare therefore measured the ratio of female/male weight for all fertile offspring taken together in nests of 21 different ant species. The average weight ratio—or investment ratio—is remarkably close to 3:1. This is impressive enough, but the clincher in the argument comes from studies of slave-making ants. Here, the workers are captured members of

other species. They have no genetic relationship to the daughters of their imposed queen and should not favor them over the queen's sons. Sure enough, in these situations, the female/male weight ratio is 1:1—even though it is again 3:1 when workers of the enslaved species are not captured but work, instead, for their own queen.

Kin selection, operating on the peculiar genetics of haplodiploidy, seems to explain the key features of social behavior in ants, bees, and wasps. But what can it do for us? How can it help us understand the contradictory amalgam of impulses toward selfishness and altruism that form our own personalities. I am willing to admit—and this is only my intuition, since we have no facts to constrain us—that it probably resolves Freud's dilemma of the first paragraph. Our selfish and aggressive urges may have evolved by the Darwinian route of individual advantage, but our altruistic tendencies need not represent a unique overlay imposed by the demands of civilization. These tendencies may have arisen by the same Darwinian route via kin selection. Basic human kindness may be as "animal" as human nastiness.

But here I stop—short of any deterministic speculation that attributes *specific* behaviors to the possession of specific altruist or opportunist genes. Our genetic makeup permits a wide range of behaviors—from Ebenezer Scrooge before to Ebenezer Scrooge after. I do not believe that the miser hoards through opportunist genes or that the philanthropist gives because nature endowed him with more than the normal complement of altruist genes. Upbringing, culture, class, status, and all the intangibles that we call "free will," determine how we restrict our behaviors from the wide spectrum—extreme altruism to extreme selfishness—that our genes permit.

As an example of deterministic speculations based on altruism and kin selection, E.O. Wilson has proposed a genetic explanation of homosexuality (*New York Times Magazine*, October 12, 1975). Since exclusive homosexuals do not bear children, how could a homosexuality gene ever be selected in a Darwinian world? Suppose that our ancestors organized socially as small, competing groups of very close kin. Some groups contained only heterosexual members. Other included homosexuals who functioned as "helpers" in hunting or child rearing: they bore no children but they helped kin to raise their close genetic relatives. If groups with homosexual helpers prevailed in competition over exclusively heterosexual groups, then homosexuality genes would have been maintained by kin selection. There is nothing illogical in this proposal, but it has no facts going for it either. We have identified no homosexuality gene, and we know nothing relevant to this hypothesis about the social organization of our ancestors.

Wilson attempts to affirm the intrinsic dignity of a common and much maligned sexual behavior by arguing that it is natural for some people—and adaptive to boot (at least under an ancestral form of social organization). But the strategy is a dangerous one, for it backfires if the genetic speculation is wrong. If you defend a behavior by arguing that people are programmed directly for it, then how do you continue to defend it if your speculation is wrong, for the behavior then becomes unnatural and worthy of condemnation. Better to stick resolutely to a philosophical position on human liberty: what free adults do with each other in their own private lives is their business alone. It need not be vindicated—and must not be condemned—by genetic speculation.

Although I worry long and hard about the deterministic uses of kin selection, I applaud the insight it offers for my favored theme of biological potentiality. It extends the realm of genetic potential even further by including the capacity for kindness, once viewed as intrinsically unique to human culture. Sigmund Freud argued that the history of our greatest scientific insights has reflected, ironically, a continuous retreat of our species from center stage in the cosmos. Before Copernicus and Newton, we thought we lived at the hub of the universe. Before Darwin, we thought that a benevolent God had created us. Before Freud, we imagined ourselves as rational creatures (surely one of the least modest statements in intellectual history). If kin selection marks another stage in this retreat, it will serve us well by nudging our thinking away from domination and toward a perception of respect and unity with other animals.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

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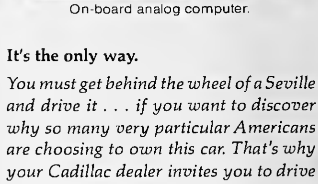

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A Resurgence of Kites

by Lee Waian

The fall and rise of a semisocial bird of prey

Several hundred yards from where I was parked, a few white-tailed kites were perched on a telephone wire that stretched across the backyards of a row of tract homes. The birds were gathering to spend the night at a communal roost located in an avocado grove adjacent to the Santa Barbara housing development. The California fall sunset was magnificent. I checked the remaining sky light with a light meter and noted the time, 5:33.

The time and light were right for the arrival of more kites, and within fifteen minutes at least seventy had flown into the area, circled, and landed on the same wire, one every two feet or so. The line of kites spanned three backyards.

Suddenly, a gunshot sent the birds up from the wire and out over the avocado trees. The kites circled the housing tract, several emitting high-pitched screams. My five years of observing kites in the field helped as I blocked out groups of airborne birds and counted 84 silhouetted shapes.

I moved quickly when I heard more shots. When I reached the area from which the shots were coming, I saw a man with a .22-caliber rifle aiming intently and firing into the sky. He was concentrating so hard that he started when I asked him what he was doing. Regaining his composure, he said, "I'm scaring those damn chicken hawks away." I asked him why he thought they were chicken hawks. "I *know* they are," he snapped, adding, "What business is it of yours, and why are you trespassing?"

I foolishly tried to reason with him. I told him that my research on kites and systematic studies by my colleague Rey Stendell had not revealed bird bones or feathers in the pellets cast by kites. We had found that kites in the Santa Barbara area lived almost exclusively on three species of small rodents—predominantly California voles, with fair numbers of house mice and a few harvest mice. But the man insisted the kites had been eyeing his chickens, and he swore he was going to shoot a few if they didn't stop landing on the telephone wires above his yard to check out his chickens. He said the kites made his chickens nervous. When he proceeded to wave the gun at me, I left. (A subsequent visit by a game warden revealed that the gentleman's chickens were indeed valuable. He had an impressive group of colorful—and illegal—fighting cocks.)

Fortunately, such a shooting incident is not as frequent an occurrence as it once was. Statutes that prohibit shooting have proved beneficial to the North American white-tailed kite (*Elanus leucurus majusculus*) throughout its range in California. This protection and, even more important, changing patterns in land use have helped account for a recent upsurge in the populations of this once severely threatened bird of prey.

In the eighteenth and early nineteenth centuries, white-tailed kites were apparently common in most of the grasslands and woodlands of California. Their original range covered the coastal area from Sacramento to Central America and all of the gulf coast from Texas to Florida. Although historical records are vague, white-tailed kites may have ranged as far north as Ohio and North Carolina.

By 1900, however, the species had been virtually extirpated in the United States and only remnant populations survived. Its current resurgence is therefore all the more dramatic. Increasing numbers of kites are being seen in the western Sierra Nevada foothills, along the northern California coast, and occasionally in southern Oregon.

This fall and rise of the white-tailed kite in California has been well documented and may typify a pattern throughout the present range of these striking birds.

Dr. Heerman, a medical doctor and naturalist for a railroad route expedition of the United States Geological Survey, noticed during an 1859 trip that kites were quite common along the California coast and flew in "small flocks" around the marshes of

An adult white-tailed kite lands on a perch near its nesting site. Males do the hunting during the nesting period, bringing their catches of voles and mice to the females, who feed the young.

George D. Lepp

upper San Francisco Bay. But the rapid influx of settlers to the region, which followed annexation of Alta California to the United States (after the 1846 war with Mexico) and the discovery of gold, brought a variety of pressures to the kites.

Egg collecting became a popular enough endeavor to pose a threat locally to some bird species. By the end of the nineteenth century, egg collectors had established white-tailed kites as a prized species, for not only did they build many of their nests in easily climbed live oaks, but their egg colors were highly variable. A collector could gather one set of nearly white eggs in the early spring, and about a month later, he could return and collect another full clutch of five eggs beautifully speckled with earth tones. One could never have enough kite eggs. In addition, kites, like hawks, were a favorite target of gunners of all sorts. Farmers thought they ate poultry; hunters thought they ate game birds. And their conspicuous white markings made them easy targets. Certainly egg collecting played a part in reducing the kite population. But even more devastating to the birds than either this activity or casual shooting was the ability of a gunner to systematically kill large numbers of kites as they came into one of their communal roosts.

The presence of settlers may have had another and more deleterious effect on the white-tailed kites. Before the end of the nineteenth century, massive overgrazing by domestic stock had nearly eliminated the native perennial grasslands, the habitat of the kites' preferred prey species. Cattle were first brought to California by

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Spaniards in the latter part of the eighteenth century. A tough, wiry breed capable of living in extreme environments, these cattle thrived in their new environment. By the mid-nineteenth century, huge free-roaming herds had developed, along with burgeoning herds of wild horses. By 1862, California's cattle population was in excess of three million. Up until the middle of the nineteenth century, most of the cattle were of the Spanish stock and were raised primarily for their hides. When California became a United States territory and the gold rush of the 1850s began, a new breed of cattle was brought west—a fatter, less mobile animal, important not just for its hide but also for its meat. Sheep, too, arrived in large numbers.

Several severe droughts contributed to some fluctuations in the size of the free-roaming livestock herds, but the pattern toward larger and larger herds continued. No one knows for certain what the natural interrelationships in the 22-million-acre native California prairie were like, for there are only scanty records and no large grasslands left to study. However, it is certain that the huge domestic herds profoundly disrupted the ecological fabric of the grasslands, especially when they were concentrated in the wetter areas, such as the margins of marshes and seasonal springs, in times of drought. Because these wetter areas are ideal California vole habitat, they are also ideal kite habitat.

Late in the nineteenth century, fences were erected to protect the growing agricultural community from cattle roaming freely across croplands. The advent of fence lines provided vestiges of grassland habitat around the fields and so were of some benefit to the kites. Seasonally wet lands were drained, filled or diked, and fenced, and these rich, marshy vole/kite habitats were transformed into grain, rice, or vegetable fields. But again, some suitable kite habitat may have been created in the drier grassland areas that were coming under irrigation, providing wet, grassy "edges." Such wet habitats must have supported small populations of voles and thereby helped sustain the surviving kites.

Other changes in the grasslands during the nineteenth century also may have helped the white-tailed kite hang on as a species. Sometime near the end of the eighteenth or early in the nineteenth century, the house mouse (*Mus musculus*) was accidentally introduced to west coast ports by ships carrying grain and other supplies from Europe. The mice quickly expanded their range beyond the docks to the towns and fields. The further spread of the house mouse was undoubtedly facilitated by the radical change of the grasslands from a primarily perennial ecosystem dominated by bunch grass to an annual ecosystem dominated by introduced vegetation. How quickly the house mouse spread to the fields no one knows. What we do know is that the house mouse was eminently successful and exists today in all types of grassland habitats in California, thereby providing the kites with an alternative prey species.

These changes were occurring during the period when the white-tailed kite was being severely reduced in number by killing, habitat destruction, and excessive egg collecting. The presence of an alternative prey species in fields during periods of meager vole availability may have helped maintain enough of a breeding stock of kites to get them through critically low population levels during the first third of the twentieth century. California vole populations undergo localized cycles of abundance, ranging from one to more than three hundred per acre during a period lasting about four or five years.

Historically, the introduced house mouse may have helped prevent the disappearance of white-tailed kites, but voles remain their staple food throughout most of their California range, and the behavioral ecology of kites suits them perfectly for exploitation of these one-ounce morsels. Kites are nomadic and semisocial. They roost and sometimes feed together and often nest in proximity. They also move from area to area, much like snowy owls and jaegers, in order to locate "hot spots" where food supplies are superabundant.

Every fall and winter during my research, a fifty-square-mile area of coastal plain north of Santa Barbara had one communal roost that served more than forty birds. Although the birds used the same roost throughout the season, various locations were used in different years. Almost invariably the roost would be within a

Four about-to-fledge kites huddle in their ample nest situated in a tangle of brush. About a month after fledging, they may be driven out of the vicinity by their parents.

mile of the largest vole habitat area in the fifty square miles.

Kites utilized the roost only at night; they arrived as singles, pairs, or loose bands of six or seven birds over a fifty-minute period at sunset and left en masse at the first hint of morning light. During the day the birds occupied defended hunting territories scattered throughout the study area. They hunted on their way to and from the roost and could therefore benefit from a relatively high vole population in another bird's hunting territory if the occupant had not yet arrived from the roost or had left for the day.

The roost population increased steadily from late September, peaked in January, and usually dropped to near zero by early April when the birds tended to remain at their nest sites. During four of the five summers of my research, few birds remained in the study area. There were no communal roosts and vole populations were relatively low.

It appears that communal seasonal night roosting has several functions. The regularity and timing of the fall and winter roosting patterns suggest a relationship to pair bonding. Chasing, calling, and other signs of intraspecific attraction are frequent behaviors at the roost sites during these two seasons. Communal roosting is also a key factor in the efficient exploitation of the California vole. Selection of the roost site is usually related to localized, cyclical vole population peaks. And birds can hunt fields with high prey densities as they travel between the roost and their daytime hunting territories every morning and evening.

Another aspect of white-tailed kite behavior helps to explain the phenomenon of communal roosting in this species: While in their hunting territories during the day, the birds exhibit aggressive behavior toward intruding kites, but at the roost they are gregarious.

On the average, an adult kite has to eat two and a half voles or about four house mice or at least five harvest mice each day, as it needs about three ounces of food daily to maintain its weight of approximately eleven ounces. California voles are active twenty-four hours a day, but more activity occurs at dusk and dawn. Harvest mice are mostly nocturnal, and house mice fall somewhere in between. Kite hunting behavior mainly reflects the daily rhythms of voles as the birds hunt most often in the morning and evening.

When hunting for prey, kites hover 20 to 100 feet in the air. With a forty-inch wingspan, a white-tailed kite can remain in a stationary, hovering position for half a minute; then—having spotted a vole or mouse—it folds its wings above its body and drops almost vertically to the ground.

No one knows how kites actually strike and kill their prey. We have studied slow-motion photography of their descent, which can be best described as a parachute drop at a slightly acute angle. During the last few feet before touching the ground, the kite's head tilts lower than its tail and the speed of the drop increases dramatically, but the critical last inches get lost in the grass. When a hunt has been successful, the kite will usually stay on the ground for several seconds before carrying its kill to a favorite eating perch. If a hunt is unsuccessful, the bird is up quickly and often flies to another hover position, searching the ground for whatever clues it uses for finding its prey.

I have tried to figure out what these hunting clues are by climbing trees in fields over which the birds were hovering. Except for fields having extremely high vole populations, I never saw any voles in even moderately high grass, even with the help of binoculars. One clue may be that voles move the grass in a telltale manner as they forage.

The male kite does not always eat what he kills. Part of kite courtship ritual follows a pattern similar for many bird species in that the male provides food for the female. Often the male will fly to where the female is perched and the vole or mouse will be transferred there. On other occasions the male will fly up with the female and the prey will be exchanged in flight. The female adroitly snatches the morsel by tilting upside down beneath the male as he hovers, dangling the vole or mouse in his talons. These spectacularly precise maneuvers continue throughout the nesting period, because it is the female that usually feeds the young while the male makes the kills.

Young kites normally remain in their parents' territory about a month after fledging. The adults continue to feed the young at increasingly longer intervals; and the parents, usually the male, will sometimes drive the young out of the vicinity when they are about ten weeks old if they don't leave voluntarily. The young may then join loose bands of roving birds or they may set up individual hunting territories. A juvenile may establish a defended territory as early as four months after its first flight.

Kite breeding behavior reflects the seasonal pattern of rain, growth of grass, and resultant increased vole populations in the Santa Barbara area. Annual grass seeds begin to germinate after the first major fall rains; however, grass growth is usually slow through the short days of winter. The grasses begin to grow rapidly by late February or early March. The California vole breeds nearly year-round, but population peaks generally occur from late fall to spring as fresh grass shoots become increasingly available for forage. The kites also nest nearly year-round, but the majority of successful nests occur during the spring.

The behavioral repertoire of the white-tailed kite suits it well to the natural patterns of perennial grassland growth and vole and mouse activity and abundance. Man abruptly disrupted the patterns and mindlessly persecuted this bird of prey. But the hunting and breeding adaptations of the kites have made it possible for the birds to stage a comeback under today's more favorable conditions.

Most present-day southern California grasslands are dominated by either introduced annual grasses and wild oats or by several species of *Bromus*. These annual grasslands provide a "fast food service" for kites because of the voles and mice they support. Even when they are

Juveniles (captive bird shown) often join together in loose bands after leaving their parents' territory. Some juveniles establish hunting territories four months after their first flight.

Tom Myers; Photo Researchers

plowed, successional patterns are such that within a couple of years there is enough forage for significant rodent populations, and so the land develops into a hunting area for kites.

Another phenomenon has led to a relationship between man and kites that is not without a touch of irony. Since the Second World War, California land speculators have gobbled up tracts of agricultural land near metropolitan areas. More often than not, agricultural practices are reduced or abandoned while the speculator waits for land prices to go up (and incidentally gets a tax write-off on his losing agricultural operation). As these lands go fallow, habitat for many native grassland species increases. Since kites build their rather haphazard nests in almost any kind of tree, even in coyote brush less than six feet off the ground, they are able to utilize many of the fallow fields as feeding and nesting territories.

The greatest period of human population growth and housing expansion occurred after World War II, through the 1950s, and into the early 1970s, overlapping the increase of the kite population. The lull between purchase of agricultural land by speculators and development of these lands partially explains this paradox; one that became increasingly important as farms became larger and more mechanized, thereby eliminating many of the habitat edges along fence lines.

There is one other bright spot for the future of the white-tailed kite: fire. Fires have been vital to the natural cycles of a variety of California habitats. Of importance to kites is fire in chaparral communities. Several million acres of California coast and inland ranges are covered with chaparral, much of it within national forest boundaries. After a fire in these dense, brush-covered slopes, which do not support voles or the right species of mice for the kites, wild grasses predominate for a few years in the successional pattern back to chaparral.

Prior to the arrival of European man, fires occurred naturally in chaparral communities at regular intervals. But we have become proficient in preventing the smaller fires, and now when there is a burn it often becomes a widespread conflagration due to the accumulation of large amounts of litter and dead undergrowth. To prevent the potentially catastrophic erosion resulting from the torrential rains of winter that follow a typical late-summer or fall fire, fast-growing grasses are sown by helicopter. This combination of natural succession and artificial seeding of grasses following a chaparral fire has proved beneficial for the white-tailed kite.

Several colleagues and I have car-

The distinctive white underbody and the habit of communal roosting made the white-tailed kite an easy target for shooters. Protective legislation has reduced this threat to the birds.

ried out vole- and mouse-trapping investigations in burned-over chaparral plots and adjacent unburned areas. We found that grassland vole and mouse populations of the right species for kites were present in significant numbers in the burned areas within a few years after the fires. Kites move in to hunt and establish territories in burned-over chaparral communities, areas unsuitable for the birds prior to the burn.

Not all chaparral fires are natural or unintentionally set. There is a growing interest in California in controlled burning of chaparral. Carefully designed patchwork burning of chaparral keeps fires from reaching catastrophic proportions. The grassy areas that are a by-product of controlled burning will increase forage for cattle; kites will also benefit from these efforts.

The recent increase in the population of white-tailed kites in California augers well for the future of the species because it has resulted in part from a beneficial relationship with man's activities. Land-use patterns, controlled burning of chaparral communities, legislative protection, and a greater awareness of the value of birds of prey should make the white-tailed kite an increasingly familiar sight over the housing tracts and open fields of California. □

Donald H. Fry, Jr.

The Ape in Stateroom 10

by Kenneth A.R. Kennedy and John C. Whittaker

The first gorilla ever brought to this country launched American research into this genus; its pickled brain is all that remains

The young passenger's sneezes and coughs competed in volume with the foghorns sounding off the banks of Newfoundland as the S. S. *Pavonia* steered a course through choppy waters and heavy mists. It was the steamer's spring voyage from Liverpool to Boston. When the ship reached port on May 2, 1897, the focus of attention on board was the welfare of the sickly youth in stateroom 10. Several eminent Boston physicians were called in to treat him, his respiratory difficulties having advanced to an acute state of pneumonia. Quinine had been administered during the journey but without effecting any improvement in the patient's condition. The situation was becoming critical, for the patient was a VIP, or more properly, a VIG (very important gorilla), the first representative of this genus of anthropoid ape to be imported alive to the United States.

The gorilla's companion and nurse during the crossing was a Mr. Edwards, one of two brothers well known as "ape fanciers" because of their success in transporting live orangutans and chimpanzees to menageries in Europe and America. While in Liverpool, Edwards had heard that a gorilla had recently been brought to that city by a hand on an African trading ship. With the help of a local animal dealer then in possession of the creature, Edwards located the seaman, who enthusiastically recounted how he had acquired the gorilla, a prize that earned him £100 (about $500).

The gorilla had been brought down the Congo River by a party of native hunters who had found the six-month-old infant clinging to the body of its dead mother. According to this account, the mother had been killed "by a windfall that had fallen over the lower part of her, apparently as she was asleep." The weak and crying survivor of this tragedy was fed water and plantains, then taken to the hunters' village where he regained his health and was enjoyed as a pet. By the time he was a year old, he was traded to the sailor in exchange for a bolt of red cloth.

The new owner could not tell Edwards the exact location along the river where the gorilla had had his home, but he did provide the curious piece of information that the gorilla mother had measured 4 feet 8 inches in body length and was very broad across the chest. Since it is unlikely that the hunters would have made such a precise observation, the sailor himself had probably killed the adult gorilla for sport, thereby obtaining the infant, which he knew could be sold upon his return to England. Edwards decided to buy the animal.

Certainly Edwards's motives in owning the animal were as commercial as the sailor's, for the day after he had made his purchase, he turned down a generous offer from the director of a Paris zoo who attempted to negotiate a sale. Edwards speculated that the gorilla infant would be "worth thousands" once he was displayed at carnivals, on lecture tours, and in zoos throughout the United States and Canada. The American public had only seen large male baboons, which were misrepresented as gorillas by ignorant or unscrupulous keepers. By importing genuine chimpanzees from Africa, the Edwards brothers had enhanced the excitement of a visit to the Central Park Zoo in New York City. Hundreds of spectators came to see and enjoy the chimpanzees, who were affectionately known as Crowley, Chiko, Johanna, and Kitty. After their deaths, these apes were exhibited as mounted specimens in The American Museum of Natural History. The large Asiatic ape, the orangutan, was also seen in America before 1897, another contribution of the Edwards brothers.

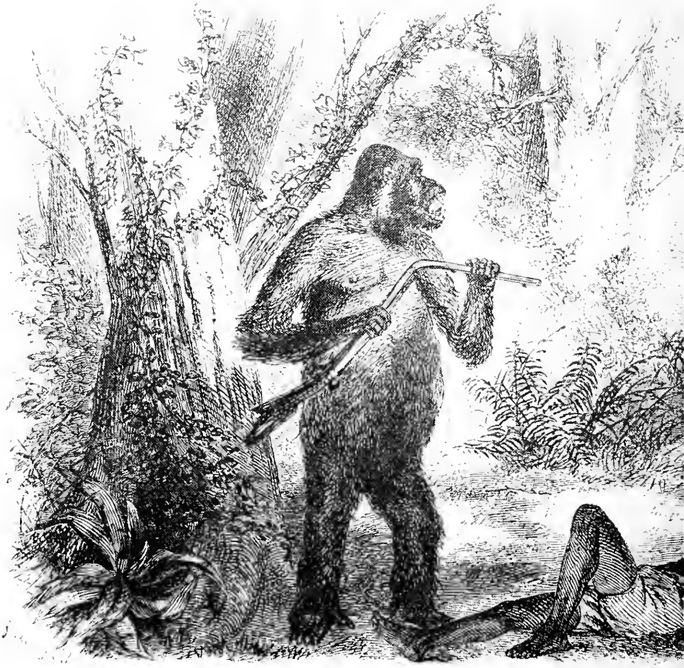
The gorilla, however, was still a creature of mystery, and Edwards knew that the debut of his latest purchase in this country would be a sensational affair—one that would attract public interest and prove to be a sound financial investment as the animal matured into full adulthood. Within a few years the gorilla would weigh several hundred pounds, exercise tremendous physical strength, and acquire those impressive sexual characteristics of massive cranial crests and ridges that give the male gorilla its ferocious appearance. Even at twelve months of age Edwards's gorilla stood two feet high, had an arm span of three feet, and weighed fourteen and a half pounds. The stakes were high for Edwards as he enjoined the elite of Boston's medical profession to do all that was humanly possible to cure his precious charge.

More is involved in this story than merely a sentimental reflection on an ailing ape. The incident occupies a modest place in the history of science with respect to the importance accorded the anthropoid apes by nineteenth-century proponents of Darwinian evolutionary theory. The gorilla is the largest of the African apes and the primate most closely resembling man in stature and body size. In *The Descent of Man,* Charles Darwin suggested that our apeman progenitor must have evolved in Africa because the most nearly manlike apes inhabited that continent.

Apart from its popularity among evolutionary biologists, the huge creature was a source of fascination to all people for its power to incite awe, in short, its "monster appeal." Many years before King Kong roared across our movie screens, travelers' accounts, novels, and representational art had popularized tales of the gorilla's ferocity and its compulsion to abduct human maidens. But the


Cornell University Archives

Travel accounts of equatorial Africa by Paul Belloni Du Chaillu, a nineteenth-century explorer-author, described gorillas as fierce and aggressive—a reputation proved false only several decades ago.



primary source of the fervor for gorillas during the last century lay in the very novelty of the beast. Before the year 1847, the gorilla was unknown to scientists in Europe and America.

The circumstances that brought the existence of the gorilla to the attention of the Western world began with a visit by the American missionary Dr. Thomas S. Savage to the Reverend J.L. Wilson, senior missionary in West Africa. Their meeting took place in 1844 in the region of the Gabon River. The Reverend Mr. Wilson showed his visitor a large ape skull and told him that the beast was called *enge-ena* by local inhabitants. Savage promptly set about collecting some skeletal specimens of his own, engaging a famous native hunter to kill a male and female *enge-ena* for him. In time he possessed the skulls and some postcranial bones of males and females of different ages.

From his own observations and those of persons he deemed trustworthy, Savage compiled detailed notes on this unique ape's manner of expressing aggression, its nest-building habits, social interactions, and other behavioral data. These notes and his assemblage of osteological specimens were shown to Jeffries Wyman, professor of anatomy at Harvard University. In December 1847, Savage and Wyman published their study of gorilla anatomy and behavior in the *Boston Journal of Natural History*, under the title "*Troglodytes gorilla,* a New Species of Orang from the Gaboon River."

Today we would not refer to gorillas as a species of orang, but the distinction between the African ape and the large ape of Asia was not understood until a few years after the appearance of Savage and Wyman's study. The name *gorilla* was chosen to honor Hanno of Carthage, who may have encountered the largest of the African apes, which he called "gorillas," while exploring the West Coast of Africa in 470 B.C. Between that date and A.D. 1847, a number of other Western explorers may have observed gorillas in the African forests, but their reports were relegated to the realm of myth. The first live chimpanzee was brought to Europe in 1641, a gift to the Prince of Orange, and the orangutan was introduced a short time thereafter, but for the next two hundred years the gorilla's existence remained unsubstantiated.

Following the announcement of Savage's discovery there was an active effort to import gorillas into Europe, but the poor beasts often arrived dead or dying from the stresses of shipboard confinement. Some gorillas reached Europe preserved in spirits, usually rum, or already prepared as skeletons. Of the few that came into port alive, most died after a few months in captivity. In 1855 the first live gorilla, a female, was brought to England. She became the property of a showman, George Wombell, but ironically he mistook her for a chimpanzee. The young animal's life in Wombell's traveling circus was brief, and she died on tour to Warrington. Another captive gorilla was exhibited at the Berlin Aquarium in 1876, but that animal lived only a few months after reaching its new home. Replacements for this Berlin specimen were dispatched from Africa in 1881, 1883, and 1885.

In France, two preserved specimens of young gorillas were brought to the Paris Museum of Natural History in 1851. These treasured specimens were later exhibited at the international exposition in Paris in 1867. A gorilla skeleton reached Paris as early as 1849; others arrived in 1853, 1854, and 1855. The first published account of the natural history and anatomy of apes to include the gorilla appeared in 1854, the work of the French biologist Paul Gervais. A few years later the English published the work of Richard Owen, superintendent of the natural history department of the British Museum and a distinguished anatomist.

The first gorilla skeleton brought to America was procured in 1851 by the Academy of Sciences in Philadelphia through the offices of the medical missionary Henry A. Ford. Additional skeletal specimens, which came into this country soon after-

Explorations and Adventures in Equatorial Africa, by Paul Belloni Du Chaillu, 1861

ward, found their way into the major osteological collections of museums and universities, including The American Museum of Natural History, the Smithsonian Institution, Case Western Reserve University, and Johns Hopkins University. Prior to 1897, however, only Americans who had visited certain zoological gardens or museums in Europe could describe to their countrymen the nature of the newly discovered ape.

Therefore, when Edwards brought the first live gorilla to this country some eighty years ago, the curiosity over this "new ape" was still fresh, especially as little was known of the animal's behavior in its natural habitat. This situation is apparent in an announcement that appeared in the *News Bulletin of the New York Zoological Society* for October 1897.

> The gorilla is one of the rarest animals ever shown in zoological gardens. In captivity it is sullen and lymphatic, and its objection to exercise is so violent and deeply rooted as to suggest the line of descent whence has come that arch enemy of all labor—the American tramp. The gorilla's sullen disposition and pernicious inactivity predisposes the animal to indigestion, loss of appetite and an early death. Owing to the extreme infrequency with which gorillas are captured alive, and to their refusal to harmonize with their environment when caught, their months of life in captivity are, in every case, but few. . . . Despite all the efforts of showmen exerted to obtain genuine gorillas, and also to palm off cheap and common old dog-faced baboons as genuine *Troglodytes*, no live gorilla has ever reached the American continent until the present year.

The ape imported by Edwards was particularly appealing because of his tender age, small size, and demonstrations of affection to his handlers. At the prestigious studio of Elmer Chickering, in Boston, he sat for his photograph. In one pose he is walking on the knuckles of his forelimbs, the characteristic locomotor pattern of the African ape. Scientists observed the little gorilla's grooming behavior and his other activities, details of more than passing interest, for relatively little was known about gorilla behavior beyond what had been reported by Savage, visitors to certain European zoos, and readers of the sensational book by Paul Belloni Du Chaillu.

This eccentric French-born, United States explorer-author had been reared on the West Coast of Africa where his father was a trader in Gabon. From 1855 to 1865 he journeyed extensively throughout west Africa, hunting apes (some of his ape specimens were forwarded to Wyman who carefully examined their anatomy) and collecting data for his book, *Explorations and Adventures in Equatorial Africa,* published in 1861.

Du Chaillu's own accounts of gorilla behavior, however, were frequently exaggerated and, all too often, untrue. His lack of scientific training was obvious to reputable biologists who had seen his book. This flaw in his education might have been forgiven, but he was charged with gross distortion of data, tampering with exhibit specimens, and having such an insouciant disregard for objective observation that his narrations bordered on dishonesty. His book, dismissed by serious biologists as the work of an egomaniacal adventurer, nonetheless gained great popular support for its sensational treatment of the venerable theme of the ape's ferocity and sexual aggressiveness. A century was to elapse between the date of publication of Du Chaillu's book and the first exhaustive study of gorilla behavior in the wild, the work of American zoologist George Schaller, author of *The Mountain Gorilla* (1963).

In Boston, hopes for the recovery of the young gorilla were abandoned as the uncommon visitor grew weaker. While Edwards described him as "strong as a little lion [who] fought right up to the last," his ward died within five days of arrival in port. The body was purchased by Cornell University for $50. On May 21, 1897, when the ice-packed corpse arrived in Ithaca, the *Ithaca Daily Journal* reported that

> the brain was removed at once and found to be perfectly preserved. A specially satisfactory observation was made as to the existence of the metapore, or foramen of Magendie, an orifice in the membranous root of the fourth ventricle. This is usually regarded as peculiar to man, but Professor Wilder demonstrated its existence in the orang four years ago, and believes that it exists also in the chimpanzee and in certain monkeys. All parts of the viscera, and indeed the entire body, will be preserved. Among other interesting organs is the appendix of the cecum, which occurs in no other monkeys excepting the four tailless apes; the gorilla, chimpanzee, orang and gibbon. These four apes therefore enjoy with man the doubtful privilege of liability to appendicitis.

On the gala occasion of the gorilla's arrival in Ithaca, a select company of Cornell University savants greeted it. Among them was the institution's president, Dr. Jacob Schurman, who had been Susan E. Linn Professor of Christian Ethics and Mental Philosophy before assuming his administrative duties in 1892. At the time Schurman inspected the gorilla he was negotiating the establish-

ment of the Cornell Medical College; hence his interest in the specimen was as pertinent to the matter of establishing collections for anatomy classes as it was directed philosophically to the issue of the gorilla's anatomical differentiation from man.

The most dynamic member of the company at the gorilla's reception party was Burt Green Wilder. To have succeeded in convincing the university's board of trustees to allocate $50 for a dead gorilla might seem sufficient cause for fame, but Wilder had other distinctions. During the Civil War, he was a distinguished surgeon with the Fifty-fifth Massachusetts Infantry, a black regiment; he was a graduate of Harvard Medical College; a scholar praised by naturalist Louis Agassiz as his most outstanding student; and the scientist appointed in 1867 by Cornell's first president, Andrew Dickson White, to be professor of comparative anatomy and natural history.

Wilder's interest in the gorilla brain relates to a preoccupation of certain nineteenth-century anatomists, who hoped that an inspection of ape brains would reveal significant structural differences that would distinguish humans from apes in a more definitive way than earlier comparative studies of nonneurological organs and philosophical debates had done. Some advocates of this position went so far as to suggest that the defective mental functions of human idiots had their counterparts in specific anatomical features that were encountered in the brains of normal apes.

But the Cornell professor had little patience with such ideas, siding instead with those of his colleagues who were supportive of Darwinian evolution and who recognized that upon careful comparative analysis, anatomical features of human and ape brains always turn out to be continuous variables, never isolated traits unique to one kind of primate and totally missing in the other.

Wilder's passion for brain anatomy bordered on the obsessive. In stocking a study collection, he once distributed copies of his specially printed Brain Bequest Forms to fellow scientists attending a banquet. The postmortem contributions of those people he influenced came in time to lie beside the bottled brains of sages and sinners, two-headed calves, and fossils of *Pleiosaurus*, all proud furnishings of the Natural History Museum in Cornell's McGraw Hall. In the basement of that venerable building also lived the howling cats whose destiny it was to be chloroformed and pressed into service in Wilder's laboratories in comparative anatomy.

Generations of Cornell undergraduates were influenced by Wilder, whose career at the university extended from 1867 through his retirement in 1911 and for many years beyond that date. The students were delighted with the gossip about his unruly menagerie, which legend says once contained a bear; his unabashed lectures to freshmen on hygiene and what every young gentleman should know; his efforts to bring about reforms to insure civil liberties for black people; his ardent support of the temperance movement and concern with the vices of rum; and his fruitless pleas to the administrative officers of his institution to abolish intercollegiate sports because of the time they absorbed in the lives of true scholars. Wilder's classes on comparative anatomy were extremely popular, and his pupils could always count on being shown the latest acquisitions of the Natural History Museum.

Wilder's diary for 1897 conveys his excitement at procuring Edwards's gorilla. Between May 21 and May 28 he removed the brain and made the observations reported in the local newspaper. The brain was found to have a volume of 322 cc and to be about 5 percent of the animal's total body weight. (For a mature gorilla brain, body weight ratios are about 1:300. For an adult human male the ratio is closer to 1:45.) Wilder set the commercial value of the carcass at $125. The skin was prepared for mounting, the viscera were removed and parts preserved in bottles, and the skeleton was set aside for maceration.

During that same week, Wilder lectured to the Cornell community, comparing the brain of the young gorilla to that of an adult brain of one of his donors. The latter might well have been the gift of a certain "Dr. B.," whose cerebral presence is noted, along with the newly acquired gorilla brain, among the entries in Wilder's diary for that hectic week in May. Perhaps these lectures stimulated certain members of his audiences to consider following in the footsteps of the generous Dr. B., but this detail remains unknown to us today. For many years the stuffed gorilla sat perched on Wilder's lecture

In the final scene of the remake of the film King Kong, *the huge ape dies after plunging from New York's World Trade Center.*

table in his laboratory; it can be recognized in Cornell yearbooks dating well into the present century. The animal was posed in the manner assumed in one of the pictures taken in Boston.

Although Wilder does not seem to have published a description of his new acquisition, his interest in gorilla anatomy continued through the years. In 1906 and again in 1911 he wrote letters to the *New York Tribune* correcting their statements about gorillas and proudly asserting that his was the first gorilla to arrive in the United States. He was interested in advances of primate behavioral research, and had he lived to see the progress made by psychologists Robert and Ada Yerkes with primate colonies at Yale University and at Orange Park, Florida, or the work of their German colleague Wolfgang Köhler in the Canary Islands and Southwest Africa, his enthusiasm would have known no bounds. He was aware of the discovery in 1902 of a new variety of *Gorilla* in the volcanic highlands of Uganda—*G. gorilla beringei*—distinct in various ways from the western lowland *G. gorilla gorilla* of Savage and Wyman and the *G. gorilla manyema* of the eastern lowlands.

Wilder may also have discussed with the young Henry Cushier Raven the latter's prospects for a field reconnaissance of gorilla distribution in Africa, which Raven later undertook and described in his monumental study of gorillas published in 1944. Raven must have been acquainted with Wilder's gorilla when he was at Cornell in 1918 and 1919, holding the position of curator of the Natural History Museum and the Department of Zoology. The collections that Raven assembled for The American Museum of Natural History and Columbia University constitute the core of the gorilla materials available for scholarly research today.

United Press International

What has happened to the baby gorilla whose place in the history of science we have been considering? Curiously, the specimen is not mentioned in the works of Raven, although the Yerkeses had heard about it in 1928 through a communication from W. Reid Blair, director of the New York Zoological Park. But since Blair's narration of how and when the Edwards's gorilla was acquired is incomplete and inaccurate, the facts of the matter are not properly represented in the Yerkeses' famous book, *The Great Apes*. Nor is the specimen noted in the records of any major osteological collection in this country or abroad. Perhaps the skeleton, the bottled organs, and the mounted figure lie in some dark corner of an ancient building, maybe they grace the shelves of a private collector, or possibly they have been destroyed.

But one vestige of the baby gorilla has survived—the complete cerebellum and the right hemisphere of its brain. This bottled specimen bears the original Cornell University catalog number of 3561, the only name by which the little gorilla is known to us, although he must have been given pet names by his various owners and by Wilder's students, who saw the mounted specimen every day in his laboratory.

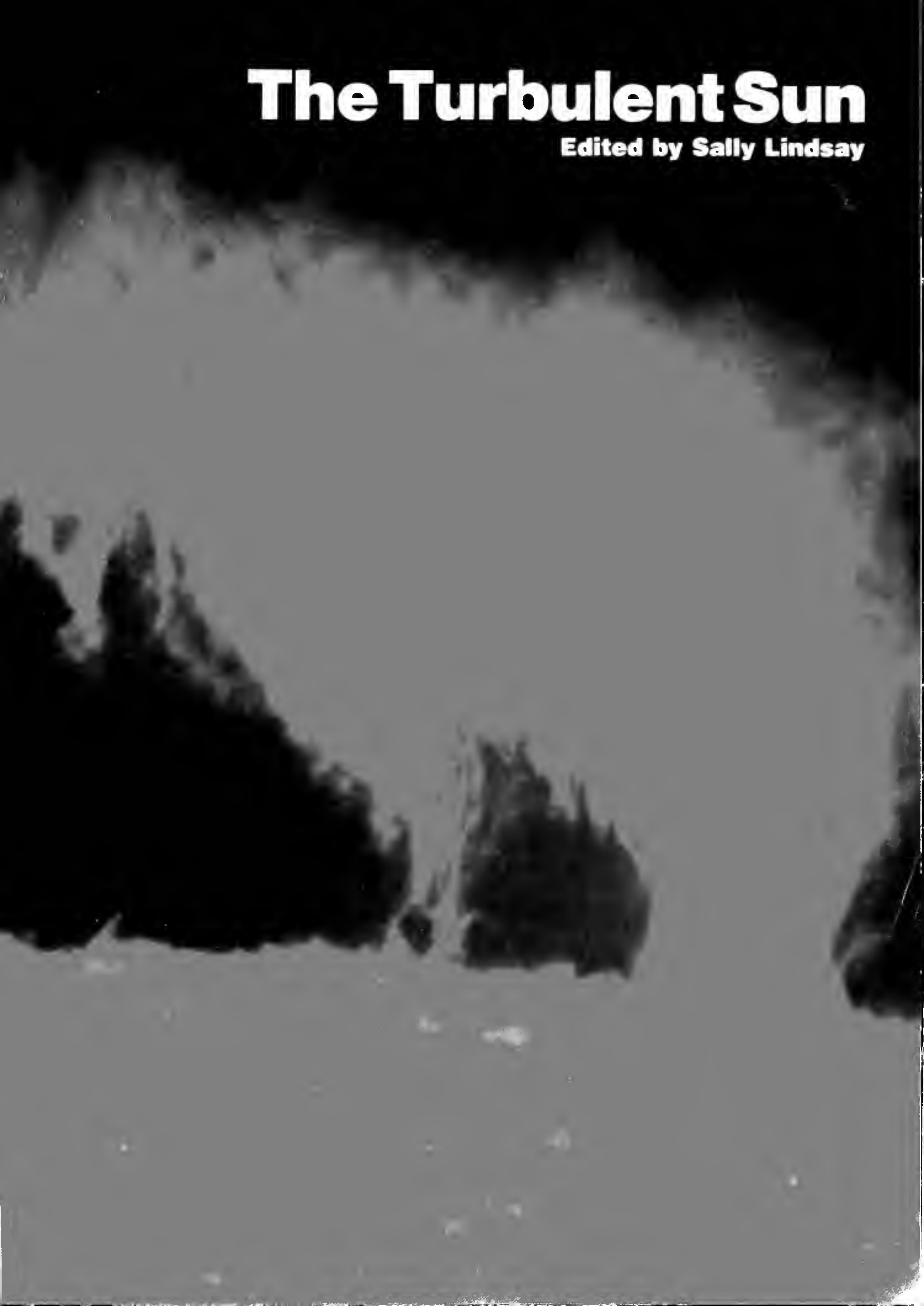
The brain now rests in its stoppered glass bottle in the company of the preserved heart of P.T. Barnum's circus elephant Jumbo, the grotesque teratological monsters, the brain of a man who slew his wife in a moment of pique, the brain of a highly moral professor emeritus of mathematics, and nearby the cerebral member of the founder of the collection, Burt Green Wilder himself. To this professor and his gorilla, American scholars can trace the beginnings of gorilla research on this continent. □

Hot gas, or plasma, leaping from the sun, forms dripping three-dimensional arches as it is trapped in the magnetic lines of force in active regions and returns to the sun's surface. These regions, which are areas of intense magnetic fields, are the sites where sunspots, solar flares, prominences, and other manifestations of solar activity originate.

Big Bear Solar Observatory (color-enhanced photograph)

The Turbulent Sun

Edited by Sally Lindsay



Introduction

How much do we know about the sun and how much do we still have to learn? Not many years ago solar physics was deemed a "mature science" in which basics were understood. For more than a century we had examined the sun's surface with the tools of spectroscopy and modern physics. We knew how much heat the sun put out and how little that radiation varied; how old the sun was and of what it was made. We knew of the eleven-year sunspot cycle, which seemed to click on like a clock. And from generations of experience in watching them, we knew the sun's varied signs of activity and called them by name: sunspots, prominences, and flares. Since 1851 we had photographed the sun at eclipse, and we thought we had come to know its slowly changing corona. We even presumed that we knew the unseen sun—the vast interior where the prodigious solar energy is created.

Then came a few surprises. When physicists were finally able to measure direct atomic particles from the center of the sun, in order to confirm the accepted nuclear process of solar energy generation, the expected particles were not there. An experiment that set out to measure the roundness of the sun found that it was not a quiet sphere of gas at all, but one that quivers.

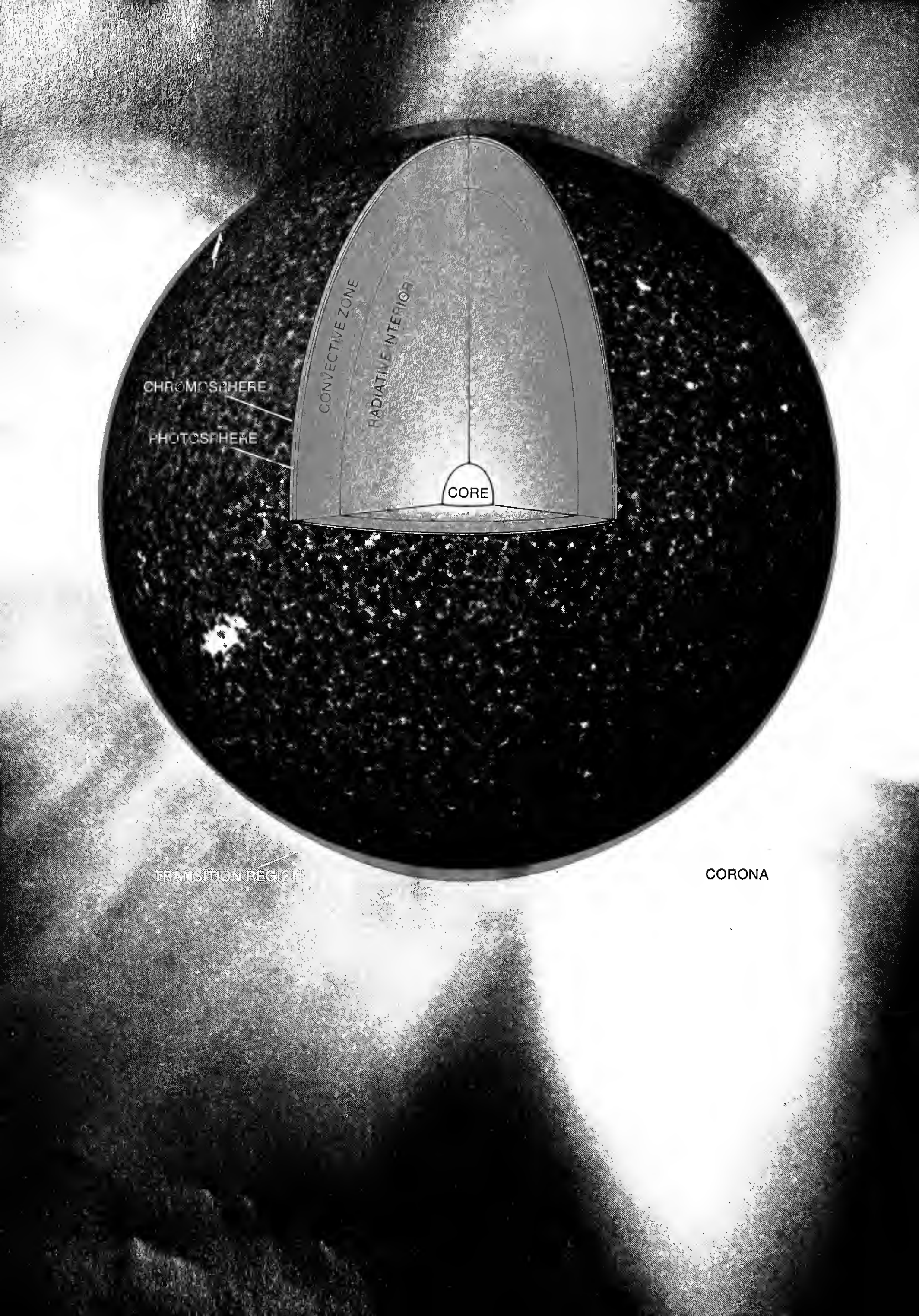
Skylab, launched in 1973 to tackle some of the remaining solar questions, uncovered a whole realm of new phenomena, like the gargantuan bubbles that are blown out almost daily from the sun and grow larger than the sun itself. With *Skylab*'s help, we have learned some, but not all, of the secrets of coronal holes, which promise to be one of the most important of solar phenomena because they control the flow of solar wind that streams against the earth.

As if these surprises were not enough, recent reappraisals of solar history and of fossil radiocarbon data have shown that the eleven-year sunspot cycle may be less like a clock than a rickety machine. For two periods since the time of Columbus, totaling more than 150 years, the cycle seems to have nearly stopped. And in 1976, as though the sun were nodding "yes" to claims that we do not yet understand it, we find ourselves in another "anomalous" solar cycle—at a prolonged minimum of solar activity that should have ended a year ago if the sun were on a regular eleven-year cycle.

We know far more about the sun than ever before, but untold questions still remain. The history of science has shown that from every new instrument and endeavor we can expect a few answers and an even greater number of fresh questions. That is the way we learn. And of the one star that controls all life and energy on earth, can we ever know enough?

J.A.E.

Naval Research Laboratory and NASA (Color-anhancad photograph)


CONVECTIVE ZONE
RADIATIVE INTERIOR
CHROMOSPHERE
PHOTOSPHERE
CORE
CORONA

Résumé for the Sun

The sun is a gaseous sphere. Unlike the earth and other rigid bodies, its period of rotation is more rapid at the equator than at other latitudes. Energy is generated in the solar core by thermonuclear reactions that convert hydrogen to helium. The energy is then transported outward to the sun's visible surface, the photosphere, a thin layer with a granulated texture. Just below the photosphere is a region known as the convective zone, in which columns of hot gas rise, lose some of their heat to the cooler surface, and descend to be heated again, creating convective currents in the process. Above the photosphere is an irregular region of the sun's atmosphere known as the chromosphere, and beyond that is the corona, which has no outer boundary. A solar wind of atomic particles blows continuously through the corona and outward toward the planets. Between the chromosphere and the corona is a narrow zone called the transition region, in which the temperature jumps abruptly. Temperature on the sun is hottest in the core and decreases slowly toward the surface. A minimum of about 4,300° K is reached in the low chromosphere, above which temperature rises again, reaching more than 1,000,000° in the corona. This increase in temperature in the outer solar atmosphere is caused by the energy of matter moving in the chromosphere and the transition region. The thicknesses of the photosphere, the chromosphere, and the transition region are exaggerated here.

Age: About 5 billion years

Distance from the earth: 93 million miles (about 150 million kilometers)

Mass: 333,000 times that of the earth

Radius: 432,000 miles (about 700,000 kilometers)

Solar energy incident on the earth: 126 watts per square foot

Core temperature: 15,000,000° K (about 27,000,000° F)

Photosphere temperature: 6,000° K (about 11,000° F)

Chromosphere temperature: 4,300° to 50,000° K (about 7,700° to 90,000° F)

Coronal temperature: 800,000° to 3,000,000° K (about 1,500,000° to 5,400,000° F)

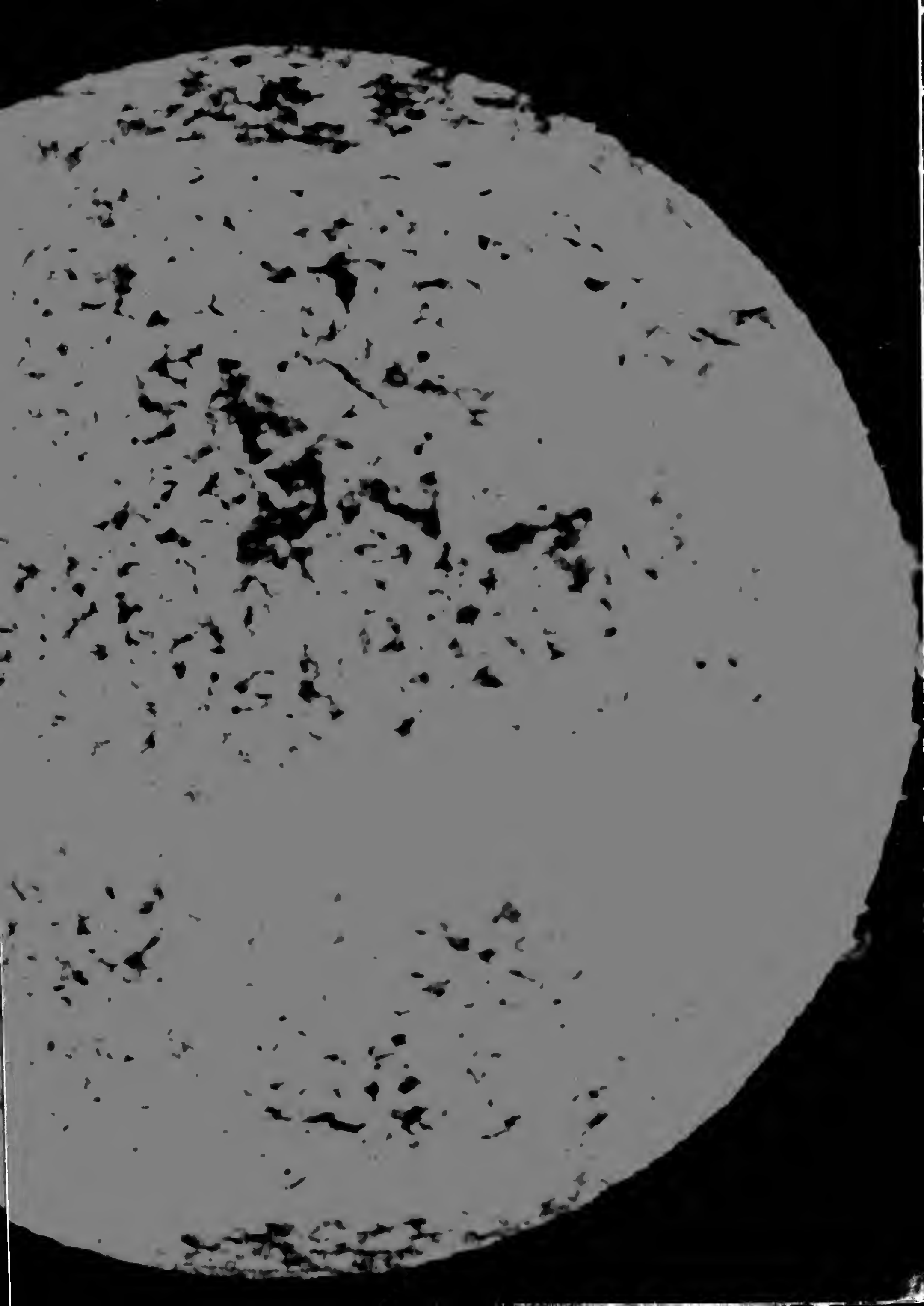
Rotation: Once every 27 days at the equator; once every 31 days near the poles, as seen from the earth

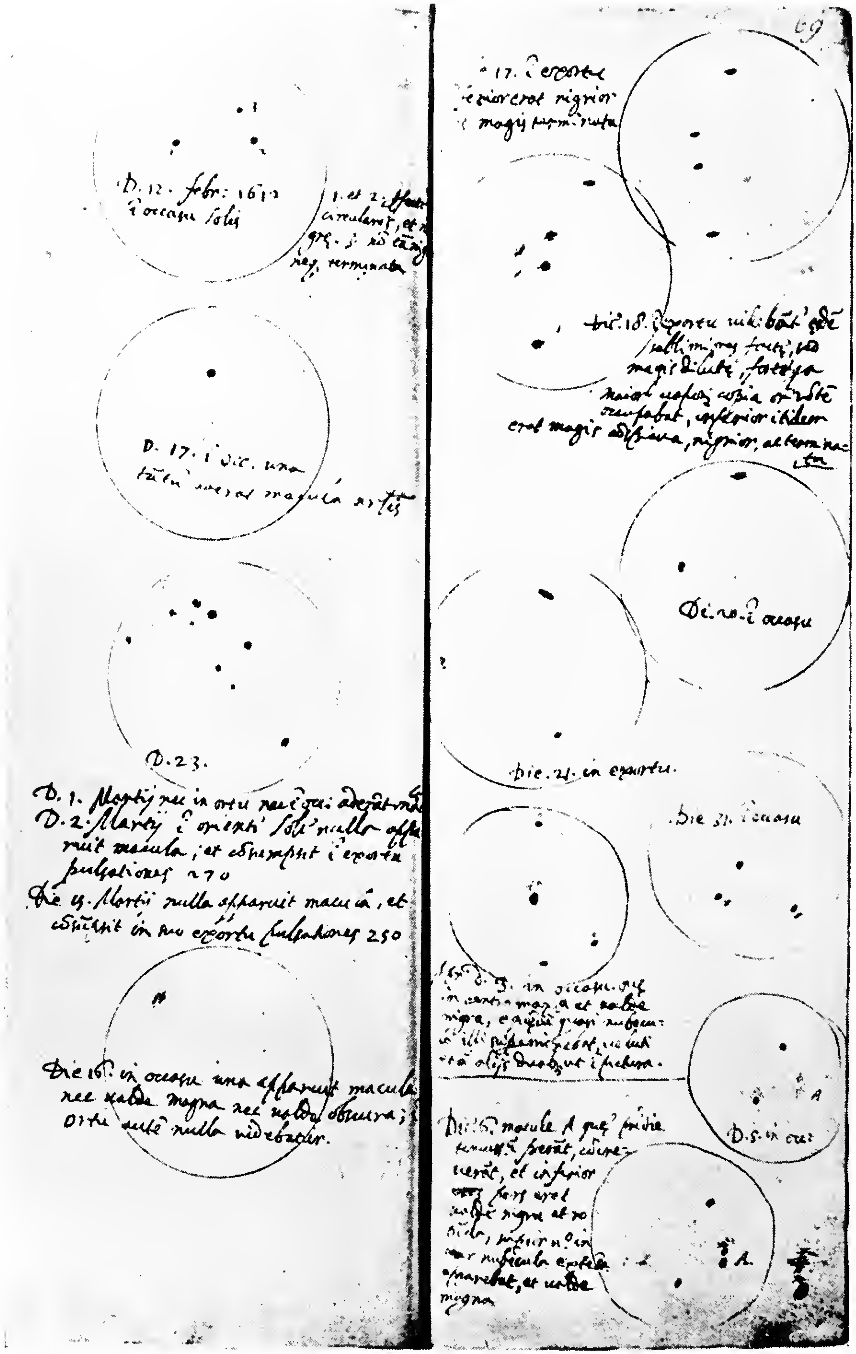
Chemical composition: About 74 percent hydrogen, 25 percent helium, and 1 percent traces of all other known elements

Photographs from High Altitude Observatory and Sacramento Peak Observatory; inset by Alan D. Iselin

A spectacular eruption, which spanned about 350,000 miles of the sun's surface and outer atmosphere, took place in December 1973.

Naval Research Laboratory and NASA (Color-enhanced photograph)





National Library, Florence

Sunspots

by John A. Eddy

These black dots associated with powerful magnetic fields do not always come and go in the expected eleven-year cycles

For many, the feature most commonly associated with the sun is *sunspots*. It is surely the best known of all solar terms and one of the few words from astrophysics that have won their way into common use and understanding. There is even a Sunspot, New Mexico (zip code 88349), which, not by accident, has a renowned solar observatory. For thousands of years, beginning long before the introduction of the telescope, sunspots have held the attention and wonder of man. They were surely the first clue that the sun, and therefore the universe itself, was not a perfect creation, but a place of turmoil and constant change.

The largest sunspots can be seen with the unaided eye at sunrise and sunset, when the sun's brilliance is dulled and reddened by absorption in our atmosphere, and we find scattered reports of dark objects on the face of the sun in historical accounts as early as the fourth century B.C. They seem to have been most thoroughly recorded in the Orient, but the record is sparse: fewer than 100 sightings are known from China, Japan, and Korea in 1,800 years preceding the introduction of the telescope. Fewer still are found in European accounts.

When the telescope was invented, in about 1610, the sun was among the first objects examined and sunspots began to be clearly seen. In popular accounts, Galileo is often credited with the "discovery" of sunspots; in truth, at least three other European scientists examined the details of sunspots with telescopes at about the same time, in 1611.

On close inspection these black dots are seen to have a distinct, dark center known as the "umbra," or shadow, surrounded by a lighter rim, or "penumbra." Under the best observing conditions, the penumbra can be resolved into separate strands that radiate outward from the umbra like threads of embroidery, being brightest at their outer ends. Careful observation of the dark umbras reveals a dim pattern of blobs, or cells, which are apparently a darkened version of the bright granulation cells that cover all the rest of the sun.

Galileo was one of the first scientists to observe sunspots by telescope. He made these drawings and notes in 1612.

The number of spots seen on the sun varies from time to time: there may be up to several hundred at once or none at all. Even when the sun is most spotted, however, the spots cover less than about 1 percent of the solar surface. Still, by terrestrial standards, individual spots are very large. An average sunspot (if there is such a thing) is about the size of the earth, and the largest could swallow Jupiter, which is about ten times earth's size.

Many sunspots are round, but oblong and amoeba-shaped examples are also common. Sunspots customarily occur in groups, rather than singly, and are restricted to bands of the middle and low latitudes on the solar surface. The simplest group consists of a pair of spots about equal in size and slightly separated in longitude—a "leader" and a "follower." But usually there are many more in one group and of all sizes, some of them interconnected by their penumbras.

Like the earth, the sun rotates on an axis, although in a longer period of about 27 days. Sunspots are carried along with this rotation. We see them first at the left (east) edge, or limb, of the sun where they seem to be flattened by the curvature of the solar sphere. About a week later the same spots appear at the center of the solar disk, where we can see them best. In about another week they disappear around the right, or west, limb of the sun. If the spots are very large, they will probably reappear in about two weeks when they will round the east limb of the sun again. Smaller sunspots last from a few days to a week; larger ones persist for several weeks and sometimes months. Spots, and groups of spots, slowly drift and change their shape as they rotate with the sun.

The same details we see in sunspots today were apparent to those who looked at the sun with the first small telescopes: the distinction between the umbra and penumbra, the varied shapes and sizes of sunspots, and the patterns of change on the solar surface. Implicit in these findings was a significant fact: sunspots are markings on the sun itself, and not, as some had proposed, obstructions in our own atmosphere or small planets circling near the sun. That revelation shattered medieval concepts of the composition of the sun and stars and marked the dawn of modern astrophysics. To seventeenth-century minds the solar nature of sunspots was a disturbing discovery for it indicated that the sun was not, as thought and taught, a perfect fire. This, in turn, had religious implications that were serious enough to cause a German Jesuit who was one of the codiscoverers of sunspots to publish his discovery under a pseudonym. Galileo was also hesitant to announce his first observations of sunspots and delayed publishing them for nearly two years.

The early theological objections to blemishes on the handiwork of God were soon assuaged by the rationalization that sunspots were only clouds that floated over an otherwise perfect solar surface. Still, astronomers continued to watch sunspot comings and goings and to wonder what the spots really were. By 1769, improved observation had found that sunspots appeared more like depressions in the sun than clouds above it, and in 1801, the eminent English astronomer William Herschel concluded that sunspots were indeed holes in a white, incandescent cloud deck that covered the entire sun. Through the umbra of each hole, he

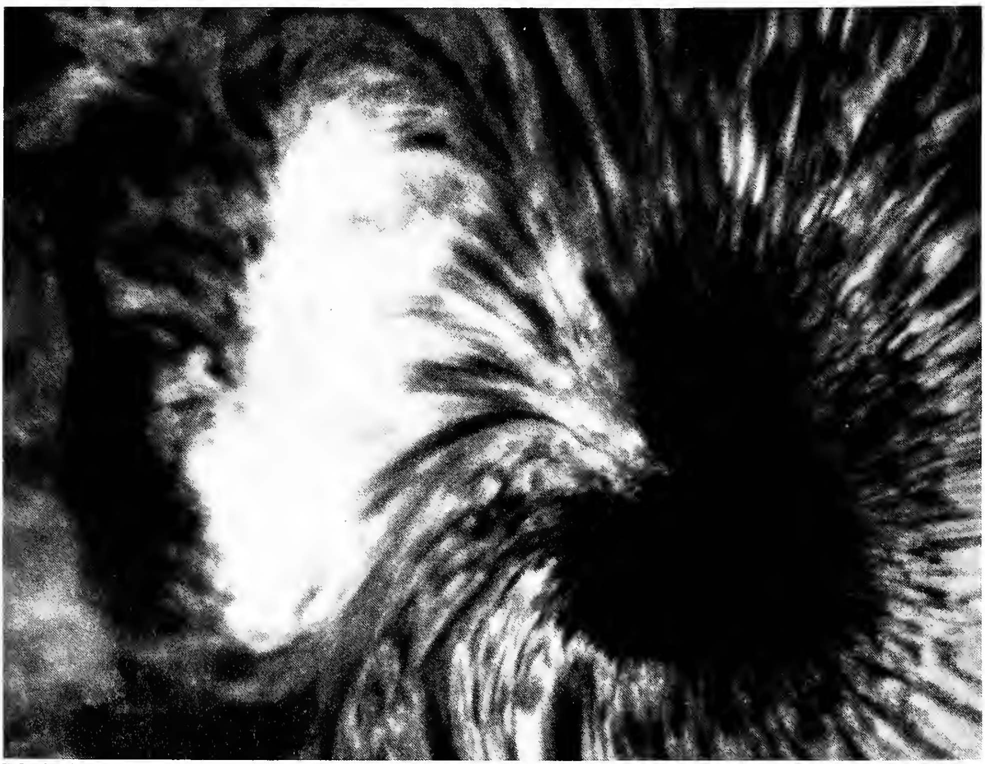
claimed, we could see the darker, cooler surface of the sun below. This lower surface, said Herschel, just might be inhabited.

Conjecture about the physical nature of sunspots gave way to another startling discovery in 1843, when Heinrich Schwabe, a German pharmacist and amateur astronomer, pointed out that the number of sunspots, when counted as annual averages, seemed to rise and fall in regular cycles. Professional astronomers, who had previously discounted notions of sunspot periodicity, soon confirmed and extended Schwabe's finding and established the nature of what came to be the best-known aspect of sunspots: the eleven-year cycle between their maximum numbers. The designation of eleven years is, in fact, just an average, since cycles of eight to fifteen years have been observed.

It took 232 years from the telescopic discovery of sunspots to the realization that their numbers were clearly cyclic. Why so long? Important among the possible answers is a recent finding that the sun's behavior may not have been constant during the centuries between Galileo and Schwabe. This possibility was first pointed out in 1889 by a German astronomer, and soon after by E. Walter Maunder of the Royal Greenwich Observatory in London, who searched historical records to show that sunspots had almost entirely disappeared for at least seventy years of the period in question—from about 1645 to 1715—during the so-called Maunder Minimum. In 1890, however, astronomers were so convinced of the regularity of sunspots that they paid little heed to dusty history.

New evidence that has come to light in the last few years seems to confirm the reality of a Maunder Minimum in sunspots and has offered a picture of a sun far less constant and regular than previously supposed. Extended work on past solar behavior, utilizing terrestrial radiocarbon as an indirect tracer, suggests that in the last 5,000 years the over-all level of solar activity (and presumably the dominance of the eleven-year sunspot

The anatomy of a sunspot is clearly visible in this photograph. The black heart-shaped region, about twice the diameter of the earth, is the umbra; the surrounding fringelike halo is the penumbra. The white area at the left has a magnetic polarity opposite that of the sunspot. Lines of force, which connect this area to the spot, are followed by dark fibrils of matter reaching to the umbra. A new 65-centimeter telescope, which may be flown on the space shuttle Enterprise, *took the picture in the Hydrogen Alpha wavelength on August 4, 1976.*



Big Bear Solar Observatory

cycle) has varied considerably, through a dozen fluctuations of the severity and duration of the Maunder Minimum. This recent finding implies that the present, regular behavior of the sun may be transitory and perhaps unusual over the relatively brief span of historical time.

Meanwhile, the twentieth-century tools of astrophysics and the genius of the American astronomer George Ellery Hale had solved the age-old riddle of what sunspots really are: why they are dark, why they appear in pairs and groups, what the umbras and penumbras consist of, and the connection between sunspots and other aspects of solar activity. Hale suspected that sunspots were really magnets, and in 1908 he perfected a method capable of measuring magnetic fields on the sun, 93 million miles away. It employed a powerful spectrograph to measure the effects of strong magnetic fields that can split certain lines in the spectrum of the sun. In the spectra of unspotted solar areas, Hale found only weak and dilute magnetic fields, but when the slit of the spectrograph was placed over a sunspot, the spectra showed the clear and unmistakable signature of magnetic fields of overwhelming strength—up to a thousand times stronger than those in the neighboring, undisturbed regions of the sun. Pairs of spots were found to have opposite magnetic polarity. Magnetic lines of force emerged from the leader spot and reentered the follower spot, breaking through the sun's surface to form magnetic arches connecting the pair. Continued studies with Hale's magnetograph showed that every twenty-two years the patterns of sunspot polarities alternated between positive and negative in a cycle exactly twice the length of the common eleven-year cycle of sunspot activity.

The picture of sunspots, clouded for 300 years, suddenly cleared. Sunspots are gigantic areas of concentrated magnetic fields, created by motions of the electrically charged particles that make up the gases of the hot solar atmosphere. One can hardly exaggerate their strength; there are no other magnets of comparable power anywhere else in the solar system. The earth's own magnetic field is more than 1,000 times weaker than that of a sunspot. These powerful magnetic fields on the sun cover areas larger than the earth, and in the seething, boiling cauldron of solar gases—hotter than an acetylene flame—they control and shape local conditions to produce what we see as sunspots.

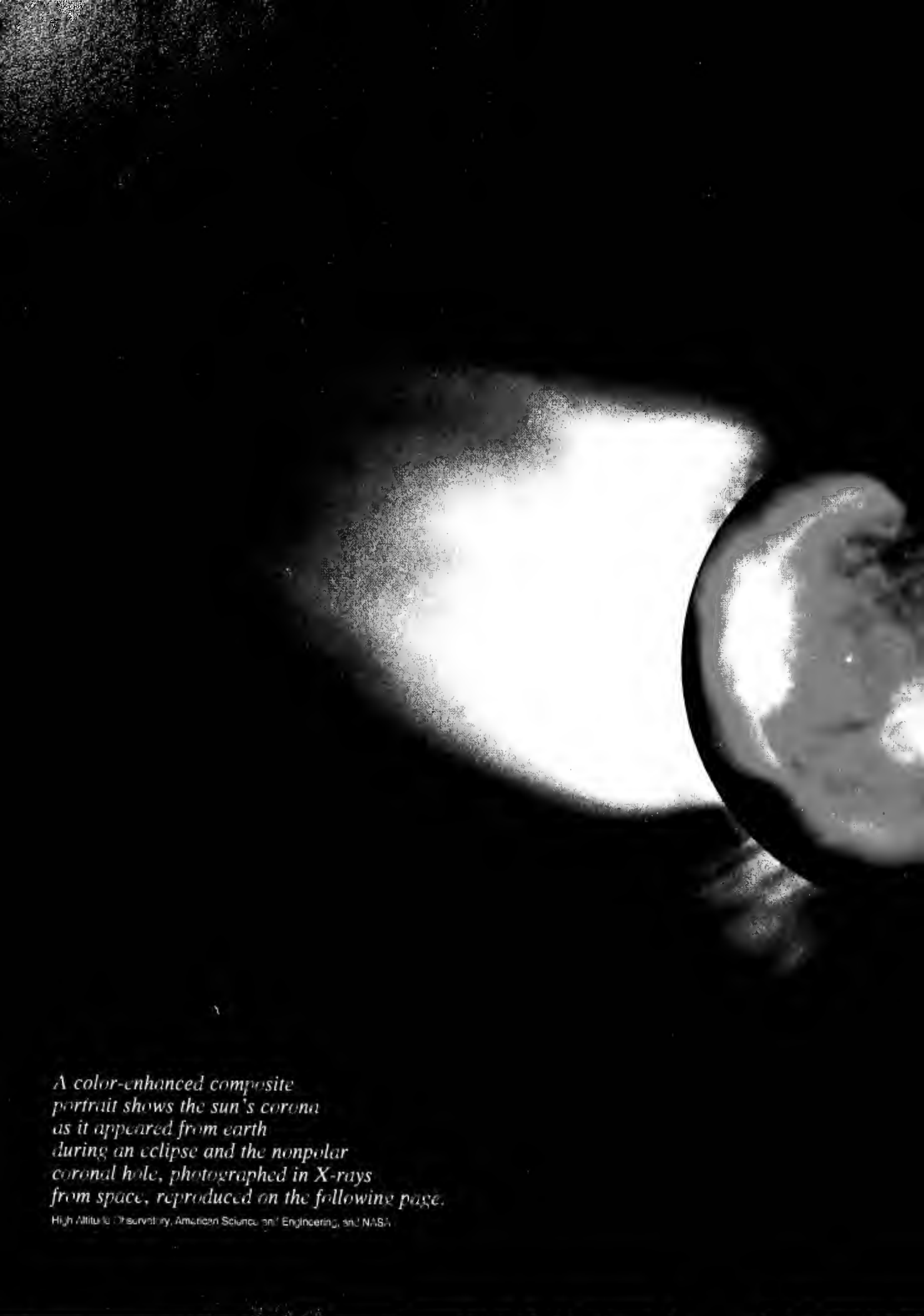
Sunspots look darker than the rest of the sun's white photosphere, which is 6,000 degrees Kelvin, because they are cooler, about 4,300°K in the umbra and 5,500°K in the penumbra. They are cooler because the presence of the intense magnetic field tends to block the normal convective flow of hot gas to the surface of the sun. The umbra is the most intense region of a sunspot magnetic field; the embroidery stitches of the penumbra are lines of magnetic force that arch upward and outward from the edges of the umbra. Streams of particles caught in magnetic lines of force soar high into the solar atmosphere to connect spots of opposite polarity and other magnetic regions. We can see the arched lines when we isolate the higher regions of the solar atmosphere—the chromosphere, transition region, and corona. The magnetic fields of sunspots appear before we ever see the spot and persist long after; it is the magnetic fields that are fundamental to solar activity and not the spots themselves, which are only one manifestation of the constantly changing configuration of magnetic fields on the sun.

We now know that almost all other forms of solar activity—solar flares, prominences, coronal streamers—are related to solar magnetic fields and are created, molded, and finally destroyed by them. The prodigious energy of disruptive solar flares, equal to the sudden explosion of a million hydrogen bombs, is derived from strong, localized magnetic fields. The flower-petal form of the corona seen at eclipse, and the patterns of loops and arches over the sun seen in pictures of the lower corona made in X-ray wavelengths by telescopes aboard *Skylab*, are all caused by magnetic lines of force, manifested in the lowest layer of the solar atmosphere.

Modern-day solar research thus centers on the study of the sun's magnetic fields and considers sunspots to be one clue to their locations, strengths, and changes. Since sunspots can be seen from the surface of the earth with simple telescopes, they will probably always be used as storm warnings of the solar system. No matter how large or magnetically strong, sunspots cannot reach down directly to earth. But they are the most convenient indicator of the day-to-day, month-to-month, and year-to-year changes in the solar energy and particles that hammer our upper atmosphere. These changes produce the aurora borealis, disturb the earth's magnetic field, and disrupt worldwide radio communications.

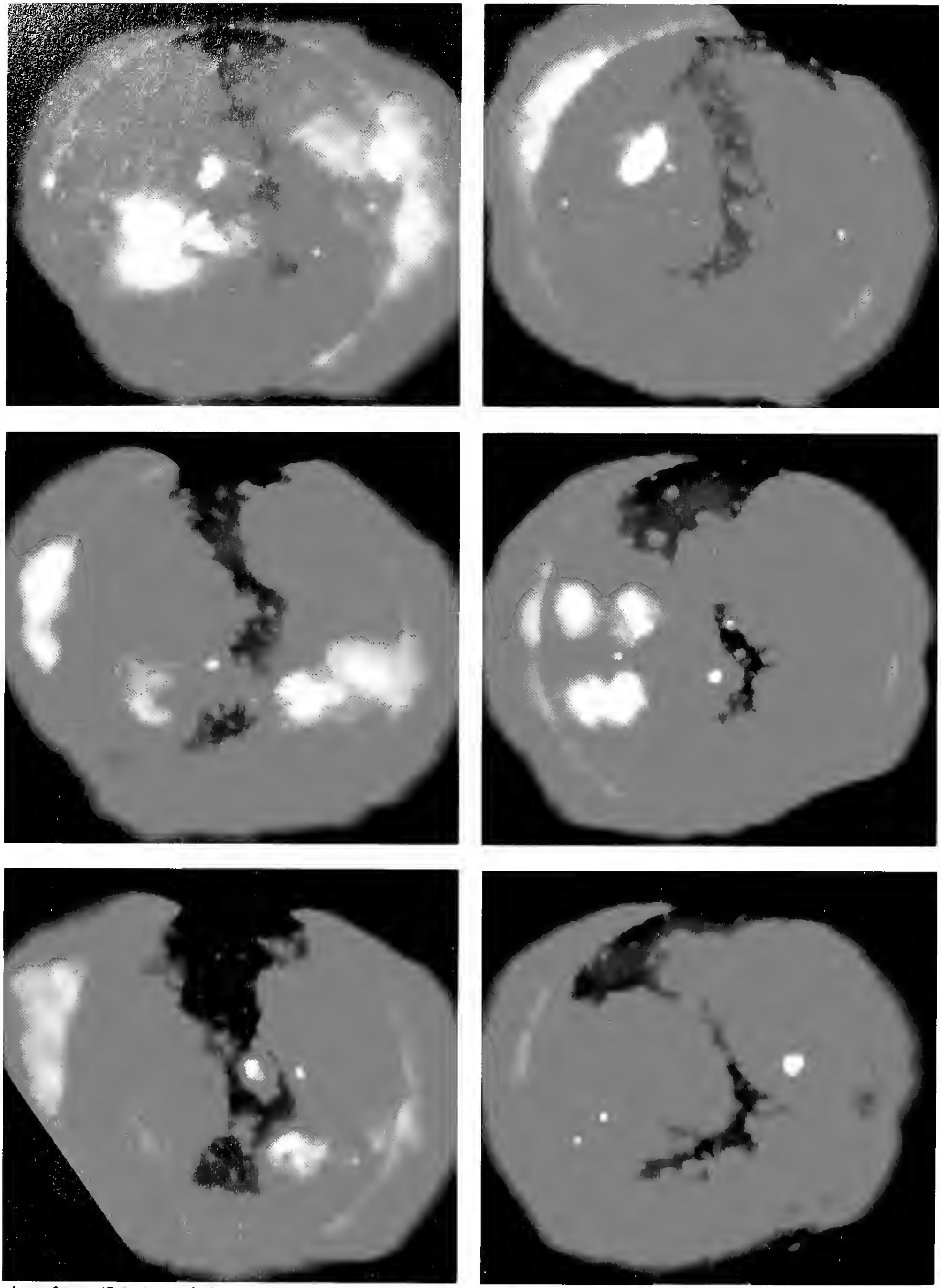
The relationship between the eleven-year sunspot cycle and variations in the earth's weather and climate has long been under investigation. Extensive studies have shown that any direct effects of the cycle on daily weather are probably small, but the longer-term changes in solar activity may well affect the longer-term terrestrial climate. At the time of each of the major changes in gross solar behavior in the last 5,000 years, the earth's climate seems to have changed, offering perhaps the best clue yet to a sun–climate connection. For example, the prolonged absence of sunspots in the late seventeenth century coincided with the worst cold of the Little Ice Age, which numbed Europe and caused the Norse colony in Greenland to perish. This line of research on the relation between the sun and terrestrial climate will surely be pursued in the future.

We have come a long way in our understanding of sunspots from the early days of the telescope. The superstition then surrounding them has been replaced by an appreciative awe for their power. Yet some mystery still persists. We think that sunspot magnetic fields are caused by motions of electrically charged particles in the sun, and that the eleven-year period in sunspots results from the interaction of these magnetic fields with other motions in the solar atmosphere. But there is still no complete explanation for the observed sunspot cycle nor can we predict the exact start and end of any given cycle. I suspect there are still other secrets of sunspots and the solar cycle whose disclosure will be as surprising in their way as was the first clear look at sunspots through a telescope and Hale's discovery of their strong magnetic fields. □



A color-enhanced composite portrait shows the sun's corona as it appeared from earth during an eclipse and the nonpolar coronal hole, photographed in X-rays from space, reproduced on the following page.

High Altitude Observatory, American Science and Engineering, and NASA



American Science and Engineering and NASA (Color-enhanced photographs)

Holes in the Corona

by J. David Bohlin

When matter escapes from the sun, it forms the solar wind, which causes geomagnetic storms on earth

The vocabulary of solar physics, like that of most scientific disciplines, has its share of strange names for various phenomena. One of the newest of these is coronal hole. Ironically, this feature, under another name, has been mentioned in the literature of astronomy for almost four and a half decades. What makes this particular solar phenomenon especially interesting is its direct effect on the earth, where it causes recurrent geomagnetic storms, that is, perturbations in the strength and direction of the earth's normal magnetic field.

The corona is the outermost part of the sun's atmosphere. It is normally visible from earth only during total solar eclipses, when the moon passes between earth and the sun, blocking from view the sun's disk, which is a million times brighter than the corona. Then for a few minutes the pearly white corona can be seen surrounding the black lunar silhouette. The cold, impersonal jargon of modern science fails to convey the ethereal beauty of a solar eclipse. One of my favorite descriptions is the simple, but eloquent, Babylonian account of the July 1062 B.C. event: "On the 26th day . . . day was turned to night, and [there was] fire in the midst of heaven. . . ."

Although the corona has been scientifically studied for 100 years, interest has centered almost entirely on bright coronal structures—streamers and condensations above the sun's active regions—where there are strong magnetic fields. Some note was made of the sun's much darker polar caps, where graceful, fanlike arrays of polar plumes are frequently seen, but for the most part, these areas of lessened coronal intensity at the solar poles were regarded only as incidental features. No serious thought was given to the possibility of similar features existing at lower latitudes. It was not until the mid-1950s that a Swiss solar astronomer using a special solar telescope at mountain altitudes was able to detect extended gaps in the corona at times other than during eclipse. He observed large and frequently persistent areas of decreased light intensity in the corona in nonpolar regions and, appropriately enough, called them *Löcher*, German for "holes." As is sometimes the case in science, his discovery went largely unnoticed.

Like the herald of a new age, the 1970 solar eclipse afforded astronomers the finest view of a lower latitude coronal hole seen to date. This was a long, east–west oriented hole located right on the southwest solar limb, with no coronal streamers in front or behind to mask its presence. This coronal anomaly was so dark that one astronomer derived from it a model based on the *total absence* of all plasma, or gaseous matter, in that part of the corona. He also dubbed the observed phenomenon a coronal hole. As its name implied, a coronal hole was then thought to be a place where the solar corona ought to be, but apparently wasn't.

It is fair to say, however, that general recognition and full appreciation of coronal holes did not occur until a few years after that eclipse. In the short period from 1971 through 1973, publication of the findings of several nearly simultaneous, but largely independent, lines of investigation established the major physical properties and significance of the holes. These studies showed that coronal holes are regions of very low density, although probably not a total absence of matter. Pictures of the sun taken in X-ray and extreme-ultraviolet wavelengths from rockets or satellites traveling above the earth's atmosphere, through which most of this radiation does not penetrate, revealed that while equatorial coronal holes are not nearly as common as active regions on the sun, neither are they rare. It was also inferred for the first time that the magnetic field within a coronal hole was probably open, rather than closed as are most magnetic fields. That is, the magnetic field lines in coronal holes stretch radially outward from the sun and do not arch back to connect to an area of opposite magnetic polarity on the solar surface. Not only was the gas density within a hole much lower than normal but the temperature was too. The typical corona has a temperature of 1.5 to 2 million degrees Kelvin; extreme-ultraviolet data showed the temperature in a lower latitude hole was only about one million degrees.

An important connection was also established between coronal holes and the solar wind. The solar wind is a continuous stream of particles accelerated by the extremely high temperature of the corona to supersonic speeds that enable them to escape from the sun's gravitational pull. The wind had been theoretically predicted as long ago as 1958 and its existence was confirmed by the first definitive *in situ* measurements made by the *Mariner 2* spacecraft on its trip to Venus in mid-1962. These same measurements also showed that the solar wind did not blow outward at a constant speed. Within it were high-velocity streams moving at about 1,500,000 miles (2,400,000 kilometers) per hour, approximately twice the speed of the steady-state, or normal, wind.

Although it had been shown that these high-speed solar wind streams were directly related to geomagnetic storms on earth, their solar origin could not be established from the usual contemporary visible-light pictures of the corona taken from the earth. The key to the mystery came when a coronal hole observed in X-rays by a rocket telescope in 1973 was shown to coincide with a well-identified high-speed wind stream.

The development and life history of a boat-shaped coronal hole near the sun's equator can be traced in a series of photographs taken at 27-day intervals—the period of the sun's rotation—with an X-ray telescope on Skylab. *The first image was made on June 1, 1973.*

To recapitulate, coronal holes are fairly large-scale areas in the solar corona. The plasma gas density in the holes is lower by a factor of ten or more than in the rest of the corona and the temperature is lower by perhaps a factor of two. The magnetic field lines in coronal holes are predominantly open and extend more-or-less straight out from the sun. Because their magnetic fields are relatively weak and their field lines are open, the holes do not trap the coronal plasma, which thus pours outward into space as high-speed solar wind streams that interact with the earth's magnetic field to produce terrestrial disturbances known as geomagnetic storms.

This last feature of coronal holes is significant because of the numerous attempts to identify the solar source of recurrent geomagnetic storms. At the beginning of this century, solar astronomer E. Walter Maunder had pointed out that major disturbances in the earth's magnetic field can recur regularly with the same 27-day period that characterizes solar rotation. Such storms, which last a few days and occur once in every solar rotation, manifest themselves as a sudden increase in the earth's magnetic field, followed by a less abrupt decrease and gradual recovery to normal. The appearance of northern lights—the aurora borealis—and interference with short-wave radio reception in the earth's polar zones often attend these disturbances.

Following the 1973 study that initially established the association of a coronal hole with a high-speed wind stream, a number of other investigations using increasingly sophisticated data have been completed, leaving no doubt about the relationship between them.

The importance of coronal holes was appreciated well enough in 1972 to lead to a comprehensive program for their study on the *Skylab* space mission, which included an elaborate array of solar telescopes. *Skylab* extended from late May 1973 through January 1974, at just the right phase of the most recent solar cycle to assure the appearance of geomagnetic storms. During that time a variety of coronal holes were observed in great detail and much of our new knowledge about holes stems directly from *Skylab* data. Three of the major solar experiments on *Skylab* made use of X-ray or extreme-ultraviolet telescopes, which can see and photograph the hot, million-degree corona projected directly against the solar surface. The sun's surface is not hot enough to emit radiation in those wavelengths, and hence, what looks like the sun's surface in X-ray photographs is really the hot corona above the surface.

One of the most spectacular findings to come from the *Skylab* mission was that coronal holes outside the polar caps can dominate sectors of the sun near the equator, appearing as jet black voids between adjacent clouds of glowing coronal gas. Holes seem to be permanent features of the polar caps, at least during the end of the sunspot, or solar, cycle. In addition, polar plumes, those enigmatic structures first noted during eclipses a century ago, are now recognized as being an integral characteristic of polar holes. Among other facts learned from the *Skylab* films is that holes, including those at the polar caps, can cover up to 20 percent of the solar surface at one time; holes outside the poles, which come and go, can last up to nine months, although four to six months is more common, making them among the longest-lived of any solar feature. Nonpolar holes occur only in the centers of large areas of unipolar magnetic fields; and their areas grow and also decay at a remarkably uniform rate of about 20 million square miles per hour. These studies of the topology of lower latitude coronal holes indicate that the overwhelming majority of them either develop as extensions of the holes at the polar caps or else acquire a connection to a polar hole subsequent to their births at lower latitudes.

The sun's surface is divided into large regions of a single magnetic polarity, giving it a patchy look. One scientist has suggested that the relationship between lower latitude holes and polar holes results from the evolution of these large-scale unipolar magnetic regions. The development of the holes is thus hypothesized to be controlled by a type of solar "plate tectonics" in which unipolar magnetic regions, any one of which can cover from 10 to 15 percent of the solar surface, are the plates. According to this theory, the gradual separation of two magnetic regions of the same polarity enlarges the intermediate magnetic region of opposite polarity in which a hole can then form. Conversely, the gradual merging of two regions of the same polarity will choke off a hole in the intervening region of opposite polarity when the converging regions get close enough to each other.

An alternate theory rests on observational data, all of which indicate that the birth of a coronal hole always follows the emergence of major bipolar sunspot groups. Prior to *Skylab* it was thought that the positive and negative magnetic areas within one active region were connected only to each other. *Skylab* observations clearly show that this situation is true only in the earliest stages of sunspot development. After a few days, areas of one polarity tend to connect with any area of opposite polarity in their vicinity. The connections between unipolar magnetic fields thus tend to be made all over the sun, from one active region to another but always from one polarity to that of the opposite sign. If, in this process, some fields cannot connect with others, their lines of force become "open" and a coronal hole is formed. This evolutionary pattern was followed by the three best-observed holes during *Skylab*, and accounts for the fact that all lower latitude holes were adjacent to large active regions rather than in the quietest portions of the sun.

No matter which theory of the origin of coronal holes turns out to be correct, their very existence and their intimate connection with terrestrial geomagnetic activity insure that coronal holes will remain a lively topic of research for some time to come. Among the major topics yet to be studied are the occurrence of holes during the maximum phase of the solar cycle, and whether or not active regions themselves may have "miniature" holes in the centers of their most intense areas of magnetic field. In addition, there is the intriguing question of whether the solar wind over the polar holes moves at uniformly high speed, as at the lower latitude holes. If so, the structure of the interplanetary medium at high solar latitudes might be quite different from what we assume it to be. ☐

Solar Flares

by Peter A. Sturrock

We do not know what triggers these explosions in the sun's atmosphere

Without special equipment we can only glimpse the sun for a fleeting moment—unless it is partially obscured by clouds, by haze at sunrise or sunset, or by the moon during an eclipse. These cursory views give the impression of the sun as a perfectly smooth ball. With the help of a piece of smoked glass, however, we can examine the sun more carefully. We then find that sometimes there are small dark spots—called "sunspots"—on the seemingly smooth solar surface.

It has been known for at least 100 years that certain natural events on earth occur more frequently when the surface of the sun is marked by spots. For instance, the aurora borealis may be seen at lower latitudes than usual when the sun is very spotty. In addition, there are certain technologically important effects, for example, shortwave radio communication may become noisy or completely useless at such times.

Are sunspots directly responsible for these effects? This seems unlikely, since sunspots do not always produce these disturbances. Moreover, sunspots may persist for months, and yet disturbances—when they occur—are comparatively short-lived. This suggests that auroras and radio disturbances are not due to the sunspots themselves but to some event that can occur on the sun's surface, or in its atmosphere, when the solar surface is marked by sunspots.

The first hint of what this event might be came from observations made in 1859. Two English astronomers, R. C. Carrington and R. Hodgson, were independently studying a large group of spots on the sun when they witnessed a remarkable event. As described by Carrington, "two patches of intensely bright and white light broke out." These patches of light lasted about five minutes, in which period they traveled a distance of about 35,000 miles across the sunspot group. Not only was this event followed by an aurora of exceptional brilliance visible at quite low latitudes but, in addition, the earth's magnetic field was disturbed for some days afterward. Such events, called "solar flares," have in recent years become quite familiar.

A solar flare is now recognized as a cataclysmic explosion occurring in the sun's atmosphere near a sunspot or a sunspot group. It is somewhat similar to a lightning stroke on earth, but whereas a lightning stroke involves a sudden release of electrical energy due to an electrical charge accumulating on a cloud, a solar flare represents the sudden release of magnetic energy due to electrical currents flowing in the sun's atmosphere. The amount of energy released in a single solar flare can be enormous—enough to supply the entire needs of the earth for over 100,000 years.

This still incomplete picture of the solar flare phenomenon has emerged in recent years as a result of both observational and theoretical advances. Systematic study of solar flares was made possible by the invention of the spectroheliograph by the American

Lockheed Solar Observatory

Igniting suddenly, like an explosion, solar flares reach their fullest extent in one or two minutes. When recorded in the Hydrogen Alpha region of the spectrum, they show up as patches of bright light. The scale of this photograph is such that its width represents about 100,000 miles.

astronomer George Ellery Hale in 1926. This instrument, which came into full operation at Mount Wilson Observatory in California in 1931, forms an image of the disk of the sun using a filter tuned to a very narrow band of the spectrum of light waves. Most work on solar activity is carried out with a filter tuned to a small part of the red region of the spectrum—the so-called Hydrogen Alpha, or Hα, line—produced by atomic hydrogen when it is raised to a temperature of about 10,000 degrees Centigrade. In this way, it is possible to observe a thin layer of the sun's atmosphere called the "chromosphere," which lies above the part of the sun we see by eye—the "photosphere."

All flares disturb the chromosphere and can therefore be observed by the spectroheliograph, but very few flares disturb the photosphere. The large flare observed by Carrington and Hodgson was exceptional in this regard. During the peak of the eleven-year sunspot cycle, astronomers nowadays may detect several small flares in the course of a day; on the other hand, they would need to wait many years to make observations in the visible, or white, light of the photosphere similar to those of Carrington and Hodgson.

The advent of spacecraft has made it possible for us to observe the sun and other astronomical objects in parts of the electromagnetic spectrum that are not accessible at ground level. For instance, most ultraviolet light and all X-rays from the sun are absorbed high in the earth's atmosphere. By mounting suitable equipment on a rocket or on a satellite orbiting the earth high above the atmosphere, it is possible to observe the sun in ultraviolet light or in X-rays. When this is done, we can examine still higher levels of the sun's atmosphere: the X-ray emission comes mainly from a very hot and extended region high above the chromosphere called the "corona." The ultraviolet radiation comes partly from the chromosphere, partly from the corona, and partly from a thin zone (the "transition region") in between.

A detailed comparison between an X-ray picture of the sun and a picture taken at the same time in Hα light (the red line of hydrogen) shows a close correspondence, indicating that the Hα emission comes from the region of the chromosphere directly underneath the large hot mass of gas producing the X-ray emission.

By analogy, if we were observing the earth from space and took photographs of both a rain cloud and the moisture content of the earth's surface, we would note that the earth is wet directly underneath the rain cloud. The same relationship exists between the hot solar cloud producing X-rays and the thin layer of the chromosphere producing the Hα emission. This is attributed to a downward flow of heat from the hot cloud to the cooler layers of the sun's atmosphere.

That a flare, when it occurs, begins very suddenly (it grows to almost its fullest extent in one to two minutes), strongly suggests that flares are some kind of explosion. In other words, we may imagine that a "bomb" is exploding in the sun's atmosphere. Is it a chemical explosion, a nuclear explosion, or still another type?

The current answer to this crucial question hinges on the fact that flares normally occur near sunspots. The true nature of sunspots was first realized by George Ellery Hale who, in addition to the spectroheliograph, invented and used another important solar instrument called the "magnetograph." Lines like the Hα line of hydrogen are influenced by a magnetic field; by suitably modifying a spectroheliograph, one can map the magnetic field strength on the surface of the sun. Such maps have been made regularly since 1953, but the first measurement of the magnetic field of a sunspot had already been made by Hale in 1908. As a result of these studies, we know that there is invariably a strong magnetic field (several thousand times the strength of the earth's field) at the center of a sunspot. We have also learned that the peculiar shapes exhibited by solar flares are determined by the magnetic field pattern of the region in which the flare occurs. This and related lines of evidence have led to the view expressed earlier on: a solar flare is now regarded as the sudden explosive release of magnetic energy in the sun's atmosphere. The nearest analogue on earth (one to which Hannes Alfvén, the Swedish Nobel laureate in physics, has drawn attention) is perhaps the bright arc produced by a circuit breaker at a power station when a generator is suddenly disconnected from the circuit to which it was supplying power.

Although this general and highly simplified picture of solar flares is widely accepted, much remains to be understood concerning their detailed behavior and the effects they produce on earth. Flares occur in a bewildering variety of magnetic field patterns and produce all kinds of radiation: radio emission, gamma rays, and particle fluxes, in addition to the visible light, ultraviolet light, and X-rays already mentioned. One is tempted to hope that a sufficiently detailed theory would enable us to predict what types of radiation to expect from a flare occurring in a specified magnetic field configuration. This is a major—and still distant—goal of solar flare research: predicting not only whether and when a flare will occur but also its properties when it does occur.

The effects of solar flares on auroras and the earth's magnetic field have been known for many years, but we are now learning more about the impact of a solar flare on technological devices. A flare interferes not only with radio transmission but also with radar operation. In recent years it has been recognized that a major solar flare produces such a strong disturbance of the earth's magnetic field as to affect the operation of power distribution networks. Some power outages are caused, not by increased demand and not by malfunction of the distribution system, but by solar flares!

Although solar flares have been studied for their intrinsic interest and for their important effects on the earth's environment, they are interesting for yet another reason. We know that explosions occur in galaxies and quasars. Although their scale is vastly greater than that of a solar flare, these phenomena are in many qualitative respects similar to flares. It is indeed quite possible that a solar flare is a small, homely example of an explosion that occurs in strange and massive objects billions of light-years away. By improving our understanding of the sun, we will not only learn something about other stars but we may also find a clue to the mystery of quasars. □

Waves on the Sun

by Roger K. Ulrich

Newly reported—and as yet unexplained—gigantic oscillations of the sun may provide clues to the star's structure

A casual impression of the sun leads one to believe that it is quite still. Apart from local disruptions, such as sunspots, prominences, and flares, there was no evidence to challenge this idea until Robert Leighton, professor of physics at CalTech, and two of his graduate students began a careful search for relatively slow-moving matter on the solar surface about a decade before the *Skylab* mission. In 1962 they discovered that the surface of the sun is actually in constant, rapid motion. The speed of motion involved is great on a human scale—1,000 miles per hour—but small compared to the speeds of 25,000 to 50,000 miles per hour found in other stars that pulsate.

The CalTech researchers discovered two types of short-period solar motion; the one that primarily concerns us here is an up-and-down vibrational movement like that of a sound wave or a spring balance. These oscillatory motions probably represent a complicated form of solar pulsation. The pulsations that are best known take roughly five minutes. During this time, the solar matter moves vertically through a total distance of 700 to 1,400 miles. The whole surface of the sun was not observed to move up and down as a single unit, as some stars are known to do. Instead, small localized portions of the sun's surface were found to pulsate independently of each other on their own time scales, although the entire surface is constantly covered with oscillatory motion. It is tempting to call these pulsations sunquakes, but that would be misleading. They more nearly resemble ocean waves.

The period of five minutes that characterizes these motions is more or less an average. A given section of the solar surface may have a period of three minutes for a while, then six minutes, and still later, five minutes. The over-all effect makes the surface of the sun resemble the chaotic surface of a choppy sea, with no easily discernible pattern to the motion.

Although the five-minute oscillations are extremely complicated, their complexity is not unlimited. Each type, or mode, of oscillation or pulsation that the sun undergoes can be classified in terms of period and horizontal scale—1,000 to 100,000 miles (1,600 to 160,000 kilometers)—and thus theoretically understood. The great complexity in the five-minute oscillations comes mostly from the fact that there are about one million ways in which the sun can pulsate and they are all occurring simultaneously. A few years ago I analyzed a mathematical model of the sun and found that its oscillations could be arranged in groups that can be distinguished from one another by careful observation. In addition to the complex five-minute oscillations, computations made as long ago as the 1940s indicated that simpler, longer-period oscillations, moving up and down through smaller distances and at a slower rate, could also theoretically be occurring. These relatively simple pulsations, perhaps best described as global oscillations, would be distinguishable from the five-minute oscillations by their longer periods, which are calculated to be from fifteen minutes to one hour.

Although waves on the sun have been known and studied for fifteen years, their use as a probe of solar structure received little attention until recently. It was then realized that solar oscillations can, in principle, reveal information about the solar interior, much as the study of seismic waves generated by earthquakes has allowed us to learn most of what is known about the interior of the earth. Seismic waves in the earth travel at a speed that depends on the composition of the matter they encounter. By measuring the time it takes waves to travel from the site of an earthquake to the measuring instruments, the detailed internal structure of the earth can be deduced. Even though the matter in the sun is entirely gaseous instead of solid, as on the earth, waves still travel through it and the speed of these waves is influenced by the distribution of the temperature throughout the solar interior. The study of solar pulsations can thus help us understand the sun's interior.

The photosphere of the sun is too opaque to allow us to see anything that goes on beneath it. The solar interior is therefore hidden from direct observation. Most of what we now believe about the interior of the sun has come from the calculation of mathematical models based on the laws of physics and assumptions about how the sun was formed and has behaved since then.

Among the more important assumptions that astrophysicists normally make are the following: (1) the chemical elements were all distributed uniformly throughout the sun when it formed; (2) any magnetic field initially present in the sun decayed rapidly and is now negligible; and (3) the matter in the solar center has not mixed with matter at the solar surface. These assumptions and others cannot be tested by conventional means. If our assumptions about the sun are incorrect, the behavior of the sun predicted by the mathematical models based on these assumptions would also be incorrect. For example, if intermittent mixing between the center and surface of the sun has taken place—a violation of the third assumption above—the amount of solar radiation received on earth would vary, with possibly dire effects. This has not happened in recent times, although some scientists propose it as a cause of past ice ages.

In the effort to substantiate or disprove our theories about the internal structure of the sun by means of solar waves, we meet one problem not faced by earth scientists. The origin of terrestrial seismic waves is known—earthquakes. But we do not yet understand what causes any of the solar oscillations. For some time after the discovery of the five-minute oscil-

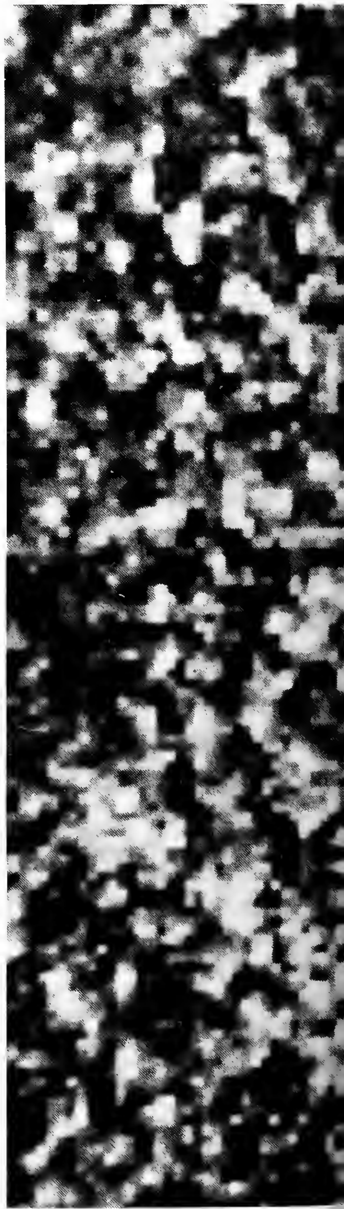
lations, it was generally believed that they were caused by convection currents, consisting of the upward flow of hot material and the downward flow of cooler material, which were striking the solar atmosphere. There are two drawbacks to this idea: the convection currents actually observed on the sun are much smaller than the oscillations they are supposed to cause; and when the velocities on the solar surface are examined, the oscillations do not seem to follow the convection currents in the way we would expect. Instead, it now seems likely that the five-minute solar oscillations are caused by the flow of energy through the layers of changing temperature in the atmosphere of the sun, as in pulsating stars. As energy flows outward from the core, it becomes bottled up in the hot, less transparent layer just beneath the solar surface until it bursts out, causing an oscillation.

The study of solar oscillations is currently entering a very exciting phase, in which we hope that sophisticated new instruments will enable us to answer many important questions about the sun. These observational efforts are being pushed in two different directions. First, observations are being made to verify the existence of the predicted simpler forms of oscillation that have periods of fifteen minutes to one hour. And second, the complexity of the five-minute oscillations is being unraveled by the continued gathering and analyzing of data, including new observations from space.

Conclusive detection of simple, long-period forms of solar oscillation postulated years ago would be truly fundamental. These oscillations penetrate to the core of the sun whereas short-period oscillations pass through only about the outer one third to one half of the sun's structure. Consequently, the study of long-period oscillations would allow us to deduce the sun's complete structure. One important advantage that the simple forms of oscillation have over the five-minute oscillations is that only a small number of their modes have similar periods. Individual configurations of long-period oscillation can therefore be isolated and investigated. Determining the particular form of any of these oscillations, however, is somewhat more difficult than determining the form of the five-minute oscillations because the scale of their action is comparable to the solar circumference and the entire surface of the sun must therefore be studied.

There have been several recent reports that these long-period oscillations have been detected. In the mid-1970s Henry Hill, a physicist at the University of Arizona, was the first to produce such evidence. By measuring with great precision changes in the visible diameter of the sun, he found indications of oscillations with periods of up to one hour. Although Hill's data are suggestive, it is not yet entirely clear that the effect he sees—the apparent change with time in the sun's diameter—is due to solar oscillations rather than to possible changes in the transparency or brightness of the solar atmosphere, to something in the earth's atmosphere, or to noise in the instruments. Calculations of solar models suggest that the periodic changes in the sun's diameter observed by Hill must be the result of actual up-and-down motion of the photosphere. If that proposition is accepted, it is then possible to calculate how fast the outer layers of the sun must be moving to match Hill's observed long-period oscillations. But the speed of motion of solar matter can also be measured by observing the shift of dark lines in the spectrum of the sun. The speed measured in the second way is about ten times less than is consistent with Hill's observations and this discrepancy raises questions.

A second problem with the data Hill has reported is the lack of stability and predictability of the motion. Such a large fraction of the sun's matter is involved in the long-period oscillations that a powerful force is required either to stop or start the motion. If the phenomena that Hill has observed are truly of solar origin, we



A graphic display of waves on the surface of the sun is produced by means of modern technology. Sensors in a telescope translate the motion of matter into light and dark areas. The image is regenerated on a television screen by a computer and the TV screen is then photographed. The light areas in this display represent matter that is moving upward; the dark areas, matter that is moving downward.

should be able to predict exactly when the sun will reach a maximum diameter. Until Hill can demonstrate that the oscillations he has observed are predictable in this fashion, I feel we must be cautious in using his observations to probe the structure of the sun. Conversely, a demonstration of predictability would establish the reality of the simple, long-period oscillations beyond a doubt.

The outer layers of the solar structure can also be probed by means of the five-minute oscillations, providing their complexity can be unraveled. In an effort to do just that, I have measured the speed of motion of matter on the solar surface about 200 million times, working with two other astronomers at UCLA and the Sacramento Peak Observatory in New Mexico. This vast quantity of measurements was made automatically by a large number of detectors, which resemble the light meters used by photographers, and the results of each measurement were stored on a computer tape. To date, we have fed 40 million of these measurements through the UCLA computer.


Sacramento Peak Observatory

The results we have obtained so far are very promising. We have been able to resolve the complicated mass of short-period oscillations into groups in just the way that the theoretical calculations indicated. (In an independent analysis, a German astrophysicist working at the Fraunhofer Institute in Freiburg has also resolved the five-minute oscillations into exactly the same groups.) We are able to determine the precise period of each group—whether it is three, five, or six minutes—with enough accuracy to enable us to set significant temperature limits on the layers of the outer half of the sun. These limits will help us test the basic assumptions mentioned earlier that are made in calculating the internal properties of the sun.

Our preliminary results lead us to the tentative conclusion that those assumptions are correct. But we are not completely confident about this conclusion because most of our measurements have not yet been analyzed and there are more complexities in our logic than we would like. We are therefore planning to continue the analysis in order to further test and resolve the five-minute oscillations into groups.

Concurrently, the observational efforts to use long-period solar oscillations as a probe of solar structure are being pushed by several research groups in addition to Hill's. There is a good prospect that within a year or two we will know with certainty whether the long-period oscillations are of solar origin. If they are, we will be able to deduce the structure of the sun all the way to the core. □

The Sun's Missing Particles

by John N. Bahcall

The unexpected results of an ongoing experiment raise basic questions about how the sun shines

Recent experimental results suggest that we do not understand as well as previously believed how the sun shines. Astronomers and physicists have thought for many years that they knew in detail how the sun produces the radiant energy observed on earth as sunlight. But they have been surprised by the results of an experiment carried out by two chemists at Brookhaven National Laboratory, Raymond Davis, Jr., and John C. Evans, Jr. There is a large, unexplained disagreement between their observations and the predictions of the supposedly firmly established theory of solar-energy generation. This discrepancy has led to something of a crisis in the theory of stellar evolution; many prominent scientists are now openly questioning some of the basic principles and approximations that were previously standard in all textbooks on astronomy and stellar aging. In fact, some of the best-known theoretical astronomers have been led to publish speculative articles in staid scientific journals that ten years earlier they would have discussed only jokingly at cocktail parties with their colleagues.

The sun is the nearest and best-observed star. We know its mass, radius, age, luminosity, and chemical composition much better than that of any other star. Moreover, the sun is in the simplest and best-understood stage of stellar evolution—the quiescent, so-called main sequence phase. Scientists believe that stars like the sun, in their stable main sequence stage, derive their energy from thermonuclear reactions that fuse the light element hydrogen into the heavier helium, thus converting mass into energy in much the same way that a hydrogen bomb works. In stars like the sun, the conversion of hydrogen into helium to provide energy is supposed to occur in a steady fashion, a gigantic, continuous, but controlled thermonuclear explosion. The theory of stellar evolution and aging by thermonuclear burning is widely used by astronomers in helping to construct a large-scale picture of the universe in which we live; many of the details in our current picture of the universe, such as its age, size, and chemical composition, are based in part on this theory of stellar evolution.

We would like to test experimentally the extent of our understanding of stellar evolution and nuclear burning in stars, but this is difficult to do directly because the sun's thermonuclear furnace is deep in the interior where it is hidden by an enormous mass of cooler material. The nuclear reactions that are ultimately responsible for the sun's radiant energy occur in the hottest and innermost solar regions, where they are effectively hidden from conventional astronomical instruments that can only record light emitted by the outermost layers of the sun (and other stars). One cannot take a picture with ordinary light of the sun's deep thermonuclear furnace.

Among the elementary particles released by the assumed thermonuclear reactions in the solar interior, only one—the neutrino—has the ability to travel unimpeded from the center of the sun to the surface and escape into space. Neutrinos are uncharged subatomic particles, familiar from laboratory physics studies, that are given off in nuclear reactions. The principal characteristic of neutrinos for our purpose is that they interact very weakly with all matter. An ordinary neutrino, of the kind we are discussing, can pass through the entire sun with only one chance in ten billion of being absorbed. It can traverse the entire earth with only one chance in a thousand billion of being absorbed. Thus neutrinos offer the unique possibility of "looking" into the solar interior and testing directly and quantitatively the theory of nuclear-energy generation in stars like the sun.

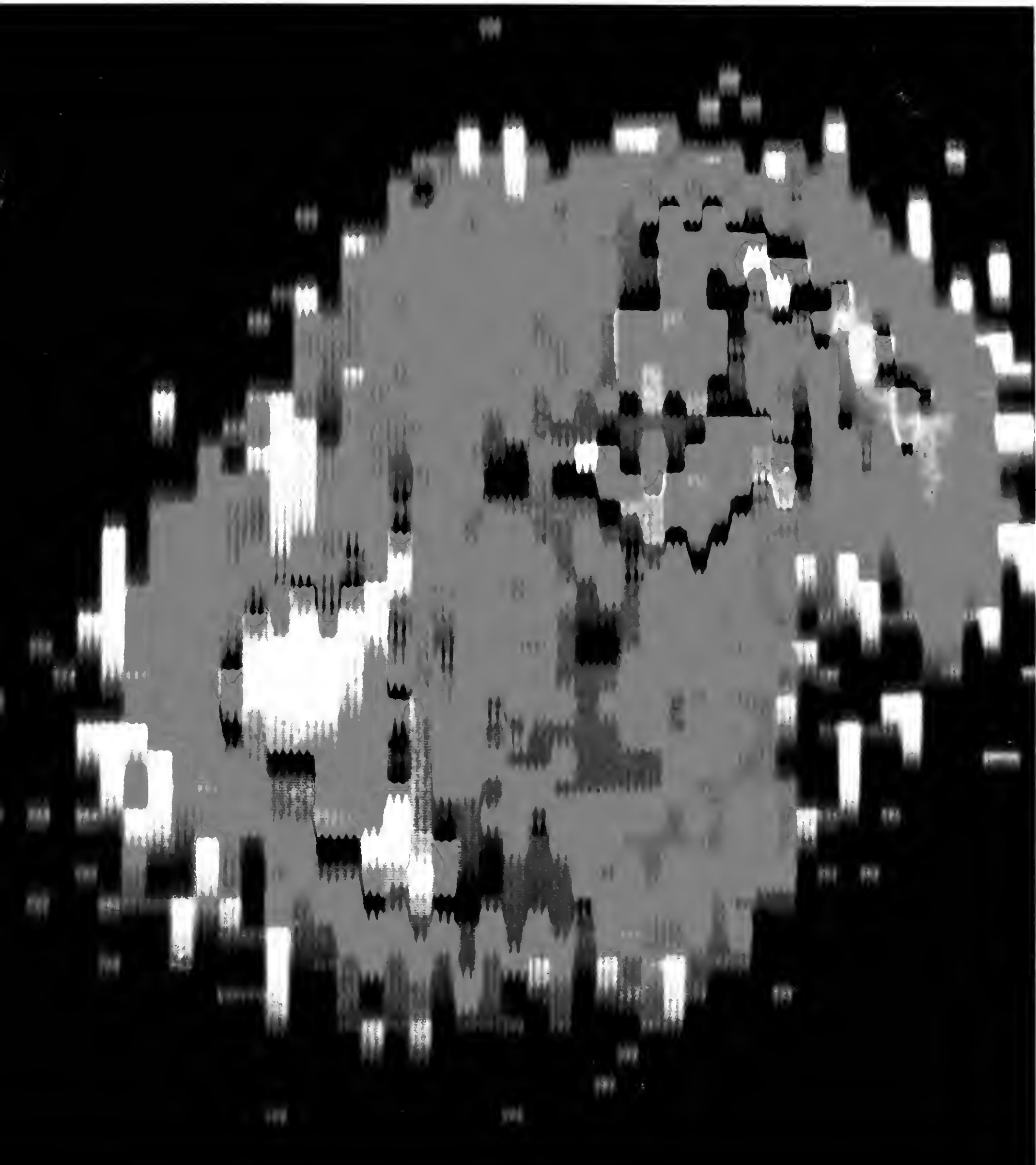
The conventional explanation of how the sun shines, that is, of the process of solar-energy generation, ascribes the phenomenon to nuclear fusion reactions, similar to those under study today for use in terrestrial thermonuclear fusion reactors that are designed to produce clean, cheap power by the year 2000. The basic solar process is the fusion of four hydrogen nuclei (called protons) to create a heavier helium nucleus. In this process, two neutrinos are produced and a certain amount of energy is released. The energy released in the fusion process ultimately appears at the solar surface as sunlight. The neutrinos come directly out of the solar interior and, traveling at the speed of light, reach the earth about eight minutes after they are produced deep inside the sun's thermonuclear furnace.

In order to calculate how often, and with what energies, neutrinos are produced, one must make a detailed model of the interior of the sun using a fast electronic computer. The techniques for constructing such models are now standard and the physics involved is relatively simple. It requires that at each point in the computer model the gravitational attraction of the sun's mass on itself be exactly balanced by the pressure of the hot gas and light particles that are bouncing around inside the sun. The rates of energy generation and neutrino production are calculated by using the known rates of the relevant nuclear reactions, which are derived from laboratory measurements and standard theoretical calculations.

Energy is transported in the solar

Intense solar activity—probably a flare—was viewed in ultraviolet light by a spectroheliograph on an unmanned satellite on August 2, 1972. Received in digital form, the picture was reconstructed by a computer-driven color television system. The white regions at the left represent the areas of highest temperature. The yellow and red clusters denote slightly cooler areas. This "solar storm" disrupted communications and power systems around the world.

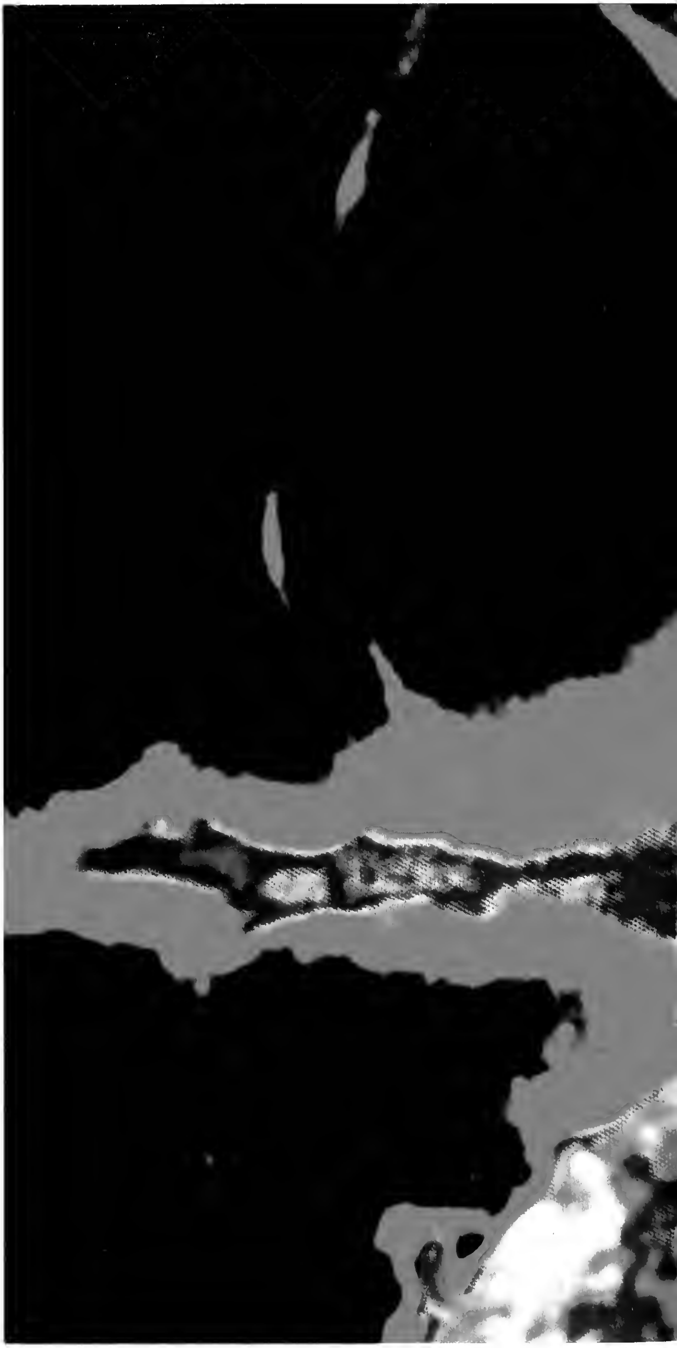
NASA



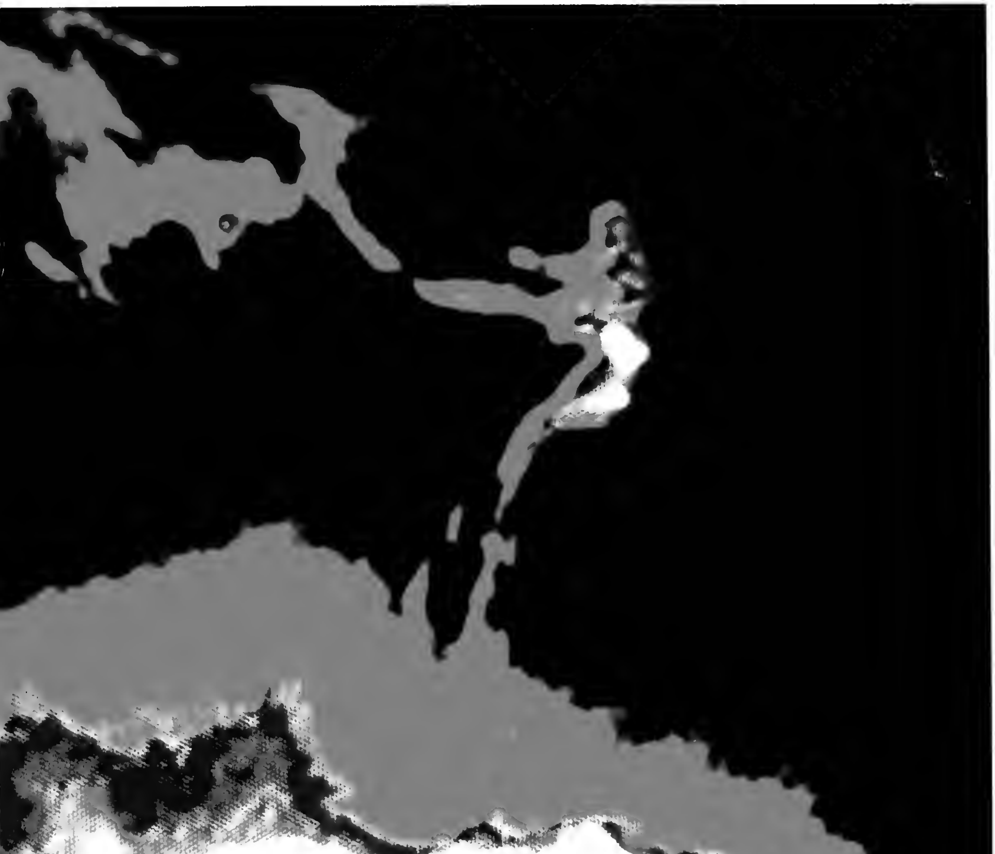
interior, for the most part, by particles of light known as photons. This is the same mechanism whereby energy is transported in the earth's atmosphere via light radiation through electrically charged, or ionized, gas particles. Thus, familiar relations can be used in modeling the sun's interior. It is conventional to assume that the sun's primordial chemical composition was homogeneous throughout and that its observed surface chemical composition at present is the same as it was when the sun was born. One then makes a sequence of successive solar models with a computer, requiring that the calculated flow of energy be equal to the observed solar luminosity at a model age of five billion years, the believed present age of the solar system.

To detect the neutrinos theoretically produced in this process of solar-energy generation, a giant neutrino trap has been operated by Davis and Evans for a number of years in a rock cavity deep below the surface in the Homestake Mine in Lead, South Dakota. The trap is a tank filled with 100,000 gallons of an ordinary cleaning fluid containing an isotope of chlorine. The trap, referred to as the Brookhaven detector, can capture elusive neutrinos by means of a reaction involving an isotope, chlorine 37, that is present in great quantity in the cleaning fluid. The neutrinos captured by chlorine produce a radioactive isotope of argon, argon 37, which can be counted with standard techniques once it is extracted from the tank by purging with helium gas.

Davis and Evans have so perfected their chemical techniques that they are able to isolate and count even the few radioactive argon atoms that might be produced in the 100,000 gallons of cleaning fluid. They can find a few atoms in a tank about the size of an Olympic swimming pool!



An enormous solar eruption, which lasted several hours, was photographed in extreme-ultraviolet light and then processed in false color—shown here—to indicate different densities of matter. The darker the color, the thicker the eruption. The sun's limb can be traced along the top of the white areas.


Naval Research Laboratory and NASA

Extreme skill is required in order to detect any solar neutrinos since the very fact that neutrinos escape so easily from the center of the sun implies that they are difficult to capture.

About fifteen years ago, I first calculated the rate at which solar neutrinos would cause chlorine 37 to change to radioactive argon 37 in the Brookhaven tank. I also made estimates of the solar neutrino production rate using conventional computer models of the sun. The theoretical predictions are most conveniently expressed in terms of a unit that, as an inside joke, I originally named a SNU, pronounced "snew." A SNU is one solar neutrino unit (10^{-36} captures per target atom per second). This corresponds to one neutrino captured every five days in the Brookhaven tank. The typical prediction of conventional solar models is that the rate of capture of neutrinos in the Brookhaven detector should be about 5.5 SNU, or about one a day.

A set of fourteen experimental runs has been carried out in the neutrino tank by Davis and Evans over the past few years. To our consternation, their results are clearly inconsistent with the rate predicted by standard models of the sun. In view of the various uncertainties in background processes, their findings have been interpreted as showing that the neutrino production rate is probably less than 2 SNU, or about one every 2½ to 3 days. However, the last several experiments performed by Davis and Evans have yielded a slightly higher rate than the average of the previous observations. The origin of this upward trend, which could be due to statistical fluctuations (my guess), experimental changes, or even solar variations, is not yet understood and another year of experiment may be required for an adequate explanation.

This conflict between observation and standard theory has led to much speculation about the solar interior, which has been advanced because proponents believed that the subject is in a state of crisis. Some scientists have speculated that the sun is not currently generating as much energy by the nuclear fusion reactions that produce neutrinos as they previously thought. It has also been suggested that the sun contains a black hole in its center and that more than half the observed solar luminosity comes from energy radiated as the surrounding gas is drawn into the hole. It has been further suggested that the sun is

The hump on the sun's surface, clearly seen in the photograph below, is part of an active region that erupted 90 minutes later, forming the stream of gas in the second picture from the left. At its maximum height, this spikelike eruption reached hundreds of thousands of miles into the corona. The third picture was made 34 minutes after the second, and the fourth was made 13 minutes later. The entire sequence was taken in the extreme-ultraviolet wavelength by a telescope on Skylab.

Naval Research Laboratory and NASA

in a transient phase during which the interior luminosity produced by nuclear reactions is much less than the observed luminosity, which results from photons, or particles of light, slowly diffusing out from the sun's interior to its surface.

These suggestions have not been widely accepted because they require the sun to be in an unusual state during the observations with the Brookhaven neutrino trap and also because there is no evidence from theoretical calculations that the dynamical behavior of the sun would be as required by these speculations.

Many astrophysicists have proposed technical scenarios in which the solar interior may be somewhat cooler than previously believed, thus inhibiting neutrino generation by certain nuclear reactions, while still permitting the observed solar luminosity to be produced by other nuclear fusion reactions.

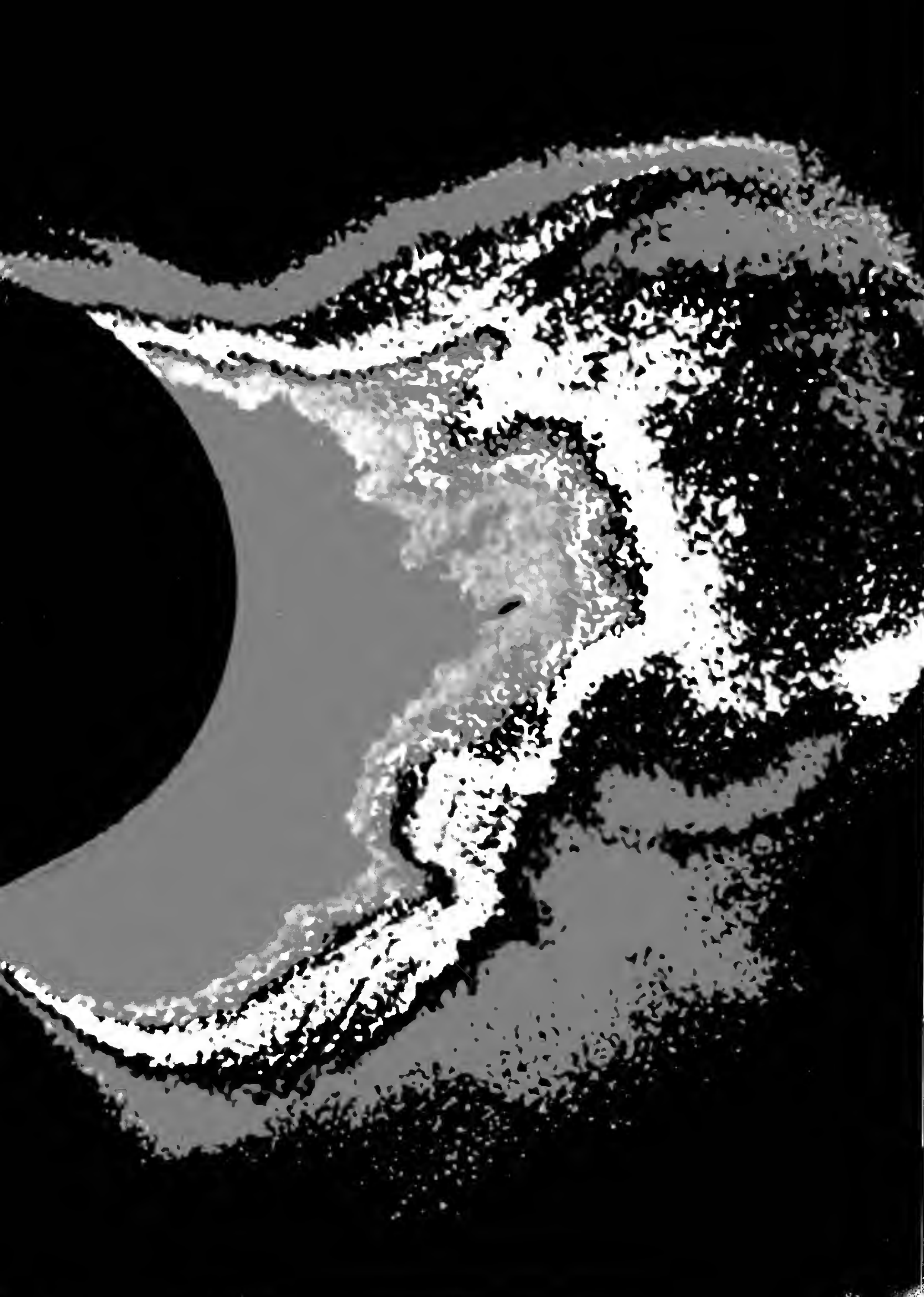
The explanation I have put forward with my collaborators is the possibility that the sun's surface contains many more heavy elements than does its interior, where the nuclear burning occurs. This suggestion is *ad hoc* and in conflict with some of the basic assumptions of the theory of stellar evolution since it negates the premise of homogeneous solar composition. Other radical assumptions about the solar interior that have recently been offered include the existence of very large central magnetic fields in the solar interior, and a critical temperature below which hydrogen and helium are immiscible. One cosmologist has even suggested that the exterior half of the sun's mass has an entirely different composition from the interior half and was added about five billion years ago.

In addition to the many speculations about radical changes in the theory of stellar evolution, it has also been suggested that neutrinos may behave differently in traversing the enormous distance between the sun and the earth—93,000,000 miles (about 150,000,000 kilometers)—than has been postulated on the basis of laboratory measurement made over small distances of less than ten meters (about 33 feet). It has been proposed, further, that a neutrino can decay, that is, transform itself into apparently unknown and undetected particles. This suggestion has not been taken very seriously by most physicists.

The attitude of many physicists toward the present discrepancy between theory and observation is that astronomers never really understand astronomical systems as well as they think they do, and the failure of the standard theory in this simple case just proves that physicists are correct in being skeptical about the astronomers' claims. Many astronomers believe, on the other hand, that the present conflict is so basic that it must be due to an error in the physics rather than in our astrophysical understanding of stellar evolution. Obviously more experiments will be required to settle the issue of the missing neutrinos and whether our astronomy or our physics is at fault. □

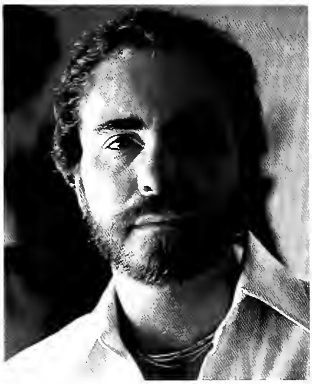
With the sun's disk blocked out to create an artificial eclipse and color added to indicate different levels of brightness, the sun's corona, as seen from the earth, looks like an abstract painting. The bulge on the right is a cloud of gas billowing outward through the corona into space.

High Altitude Observatory and NASA



THE JEMEZ BUFFALO DANCER
re shown approximately actual size) $375

THE AHÖLA KACHINA
(Figure shown approximately actual size) $47



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THE TURBULENT SUN
Additional Reading

Modern Astronomy, by Ludwig Oster (San Francisco: Holden-Day, 1973); *Introductory Astronomy and Astrophysics*, by Elske P. Smith and Kenneth C. Jacobs (Philadelphia: W.B. Saunders, 1973); and *Astronomy*, by Franklyn M. Branley et al. (New York: Thomas Y. Crowell, 1975, $14.50), are introductory books with sections on the sun. *Our Sun*, written for the lay audience by astronomer Donald H. Menzel (rev. ed. Cambridge: Harvard University Press, 1959), remains one of the best sources of background material. *Early Solar Physics*, by A. J. Meadows (Elmsford: Pergamon Press, 1970, $8.50), is a nontechnical account of the historical roots of solar studies. *The Quiet Sun*, by scientist-astronaut Edward G. Gibson (Washington: U.S. Government Printing Office, 1973), provides an introduction to solar physics prior to the launching of *Skylab*. E. N. Parker's "The Sun" (*Scientific American*, September 1975, pp. 42–50) describes recent findings (and mysteries) revealed by spacecraft-based solar observations. John A. Eddy's *A New Sun* (to be published in early 1977 by the U.S. Government Printing Office) is meant for a popular audience and will be heavily illustrated with black-and-white and color photographs from *Skylab*. The *Annual Review of Astronomy and Astrophysics* (*ARAA*) frequently contain expert articles on solar phenomena.

Sunspots (p. 62)

R. J. Bray and R. E. Loughhead's *Sunspots* (New York: John Wiley & Sons, 1965, $16) is a semitechnical work useful to amateur astronomers for its clear exposition of observational methods. "The Maunder Minimum," a comprehensive article by John A. Eddy (*Science*, 1976, vol. 192, pp. 1189–202), relates the contemporary revolution in solar research to past observations of sunspot activity. The information on sunspots in Harold Zirin's *The Solar Atmosphere* (Lexington: Ginn & Company, 1966) typifies the working literature of astronomers—technical, but readable if you skip the mathematical equations.

Coronal Holes (p. 69)

Edward Gibson's *The Quiet Sun* (1973), Eiñar Tandberg-Hanssen's *Solar Activity* (Lexington: Ginn & Company, 1967), and J. Pasachoff's "The Solar Corona" (*Scientific American*, October 1973) contain background information on coronal holes. *Coronal Expansion and Solar Wind*, by Arthur J. Hundhausen (New York: Springer-Verlag, 1972), although technical, is written in a lucid style. Two well-illustrated, key papers on these phenomena are "A Coronal Hole as the Source of a High Velocity Solar Wind Stream," by Allen S. Krieger et al. (*Solar Physics*, 1973, vol. 29, pp.

505–25), and "The Structure and Evolution of Coronal Holes," a nonmathematical description by Adrienne F. Timothy et al. (*Solar Physics*, 1975, vol. 42, pp. 135–56). For a historical perspective on coronal holes and the solar wind, see John M. Wilcox's "The Interplanetary Magnetic Field: Solar Origin and Terrestrial Effects" (*Space Science Reviews*, 1968, vol. 8, pp. 258–328) and M. Waldmeier's "The Coronal Hole at the 7 March 1975 Solar Eclipse" (*Solar Physics*, 1975, vol. 40, pp. 351–58), in which the Swiss discoverer of coronal holes analyzes a recent observation in light of his previously unnoticed work on coronal phenomena.

Solar Flares (p. 71)

Zdenek Svestka's *Solar Flares* (Boston: D. Reidl Publishing, 1976) is a highly technical, comprehensive review of observational data. Peter A. Sweet's "Mechanisms of Solar Flares" (*ARAA*, 1969, vol. 17, pp. 149–76) discusses processes of flare production. Peter A. Sturrock's "Magnetic Models of Solar Flares" (*Progress in Astronautics and Aeronautics*, 1972, vol. 30, pp. 163–76) examines the phenomena from an astrophysicist's point of view. Solar physicist Einar Tandberg-Hanssen's books, *Solar Activity* (1976) and *Solar Prominences* (Boston: D. Reidl Publishing, 1974) may prove easier to read.

Solar Oscillations (p. 73)

Charles F. Richter's *Elementary Seismology* (San Francisco: W.F. Freeman, 1958) provides a grounding in analyses of earthquake-produced movements of the earth's crust—analyses that have been applied by analogy to waves on the sun's surface. Robert B. Leighton's "The Solar Granulation" (*ARAA*, 1963, vol. 1, pp. 19–40) describes the techniques used to discover and analyze solar oscillations. "Waves in the Solar Atmosphere," by Robert F. Stein and John Leibacher (*ARAA*, 1974, vol. 12, pp. 407–36), discusses the ways in which oscillations are observed and interpreted today. R.J. Bray and R.E. Loughhead's *Solar Chromosphere* (New York: Halsted Press, 1973) contains several sections on solar oscillations.

Neutrinos and Solar Energy (p. 76)

John N. Bahcall's "Neutrinos from the Sun" (*Scientific American*, January 1969, pp. 29–37) discusses the solar neutrino problem prior to the troublesome present-day findings. "Solar Neutrinos," by Bahcall and R. L. Sears (*ARAA*, 1972, vol. 10, pp. 25–44), has become a standard reference work on the subject. "Solar Neutrinos: A Scientific Puzzle," by Bahcall and Raymond Davis, Jr., (*Science*, 1976, vol. 191, pp. 264–67), summarized the results of a fifteen-year collaboration between theorist and observer and includes a working diagram of the solar neutrino trap. *G.B.*

Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun continues its southerly drift above the earth, an apparent effect of the earth's motion in orbit around the sun and the inclination of the earth's rotational axis. The result brings continually shorter days and longer nights to the Northern Hemisphere and a shorter, lower path for the sun each day. In Libra until November 23, the sun then moves into the stars of Scorpius, but for less than a week. On November 29, the sun's motion takes it into the constellation Ophiuchus. Although that constellation is not formally counted among the twelve constellations of the zodiac, the sun (and the moon and planets as well) spends more time among its stars than it does within the boundaries of the zodiacal constellations.

Moonlight dominates the evening hours through the first week or so in November and December and the morning hours through the mid-November period. We will have an evening moon again toward the month's end. Phases in November are: full on the 6th; last-quarter on the 14th; new on the 21st; and first-quarter on the 28th. In December, the moon will be full on the 6th; at last-quarter on the 14th. A penumbral eclipse of the moon (during which sunlight will be partly obscured by earth) will occur on the 6th after moonrise, but will attract little notice.

Stars and Planets The weather may not as yet take on a wintry appearance, but the evening Star Map is already beginning to assume the look of that season, with Orion and the bright stars of other wintertime constellations showing above the eastern horizon at the times for which the map was prepared. The only planet on the map is Jupiter, in Taurus, rising at about sunset and visible for the remainder of the night. Although not shown on the map, two other planets will appear in the evening. Venus will be very bright and easy to see in the west-southwest until it sets toward the end of twilight. And Saturn will rise in the east before midnight, easy to see among the dim stars of Cancer. Mercury and Mars are not in good positions to be seen.

November 4: The weak Taurid meteors reach maximum.

November 6: Moon at apogee (farthest from earth). Penumbral lunar eclipse.

November 7: The moon passes very near Jupiter, covering it (an occultation) in the sky over South America. Mercury, at superior conjunction, enters the evening sky.

November 13–14: The bright object near the moon is Saturn.

November 16: The Leonid meteor shower reaches maximum. Do not expect to see more than 15 to 20 meteors per hour, but some can be very bright.

November 18: Jupiter is at opposition from the sun.

November 20: The moon is at perigee (nearest earth) only half a day before new moon, resulting in stronger perigee spring tides tonight and tomorrow.

November 23–24: The crescent moon passes above Venus. Mars, in conjunction with the sun, enters the morning sky.

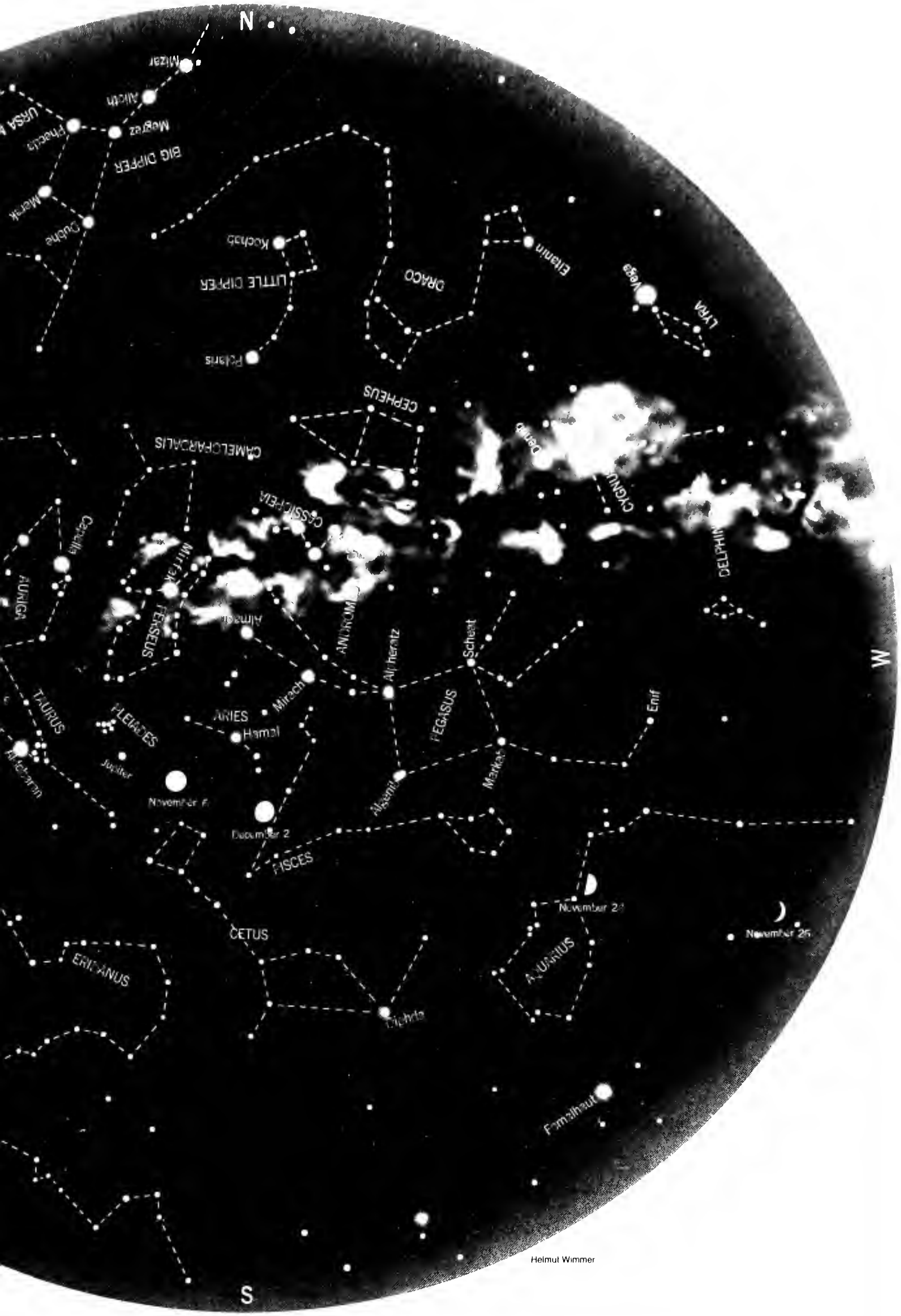
November 28: Saturn begins its retrograde (westerly) motion, causing it to move away from (to the right of) the star Regulus in Leo.

December 3: Apogee moon.

December 4: The moon is again very close to Jupiter, covering the planet over South America.

December 11: Saturn rises near the moon tonight.

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 11:10 P.M. on November 1; 10:15 P.M. on November 15; and 9:15 P.M. on November 30; but it can be used for an hour before and after those times.



Helmut Wimmer

An African Ethic of Conservation

by Hussein Adan Isack

For a young Kenyan, wildlife protection is rooted in the customs of his people

The Boran people live in northern Kenya. This nomadic tribe, with its large number of domestic animals, roams in search of pasture over vast areas occupied by wildlife. They are always armed with spears and other weapons used for defense against wild animals and fighting neighboring tribes during cattle raids. Occasionally, animals are hunted. But although this has gone on for a long time, a high population of wildlife has managed to survive due to several factors—one factor being the tribal customs.

Customs and beliefs are closely related, for it is beliefs which develop into customs. To the Boran tribe, they have the same meaning. Wars have been mentioned because war between tribes is a customary challenge that lives with the tribe. It is considered a deciding factor in determining heroes of the tribe.

The customs of the Boran, most of them practiced even today, protected some species of wildlife from being harassed or killed. Insects, plants, reptiles, birds, and mammals shared these protections.

It is believed that the killing of some birds like crows and woodpeckers can cause ill luck to the person concerned. The crow is not killed because it informs people of their coming visitor by sitting on or near the hut crying. If one killed the crow, it is believed one's visitor may be met by misfortune on his journey. The woodpecker is saved because it warns people of dangers while in the bush by producing a loud ticking noise.

Killing of the honey guide is believed to cause someone permanent inability in finding any wild beehive containing honey. Bee sting will also become fatal for him. Nobody, therefore, dares to kill a honey guide.

Eagles, hawks, kestrels, and several other birds of prey are not killed because it is believed that their death causes the killer to go berserk. The security of the birds' eggs and young ones is insured by not allowing people, especially children, to pass below a colonized tree in fear of ringworm. Although the tribe believed that they could gain by following such customs, they were also, in effect, saving many wild birds.

Certain animals like warthogs, zebras, ant bears, porcupines, elephants, hippos, and all carnivores are classified as unclean animals by the tribe and are therefore not eaten. Anybody seen eating one of these is considered as unclean too and becomes an outcast. Such a person is not allowed to live with anybody or marry anybody's daughter. Therefore apart from a few unfortunate animals that fall in the hands of people who kill them without a genuine reason, these animals are never hunted for food. Until recently, eating of fish was also considered "bad."

Bringing meat from wild animals into the village where there are cows is believed to have a bad effect on the cows. It is believed that the cows will catch a strange disease and die, leaving the owner poor. Many epidemic diseases are associated with such beliefs. This therefore reduces the number of animals being killed for food by a large number.

Sometimes special trees are protected for their importance to the tribe. A big tree that provides shade at a particular meeting place is never cut down, and a person seen doing this can be tried before a tribal court of law and heavily fined in terms of cattle. Other plants are protected for their important usage to the people. They are discouraged from cutting or

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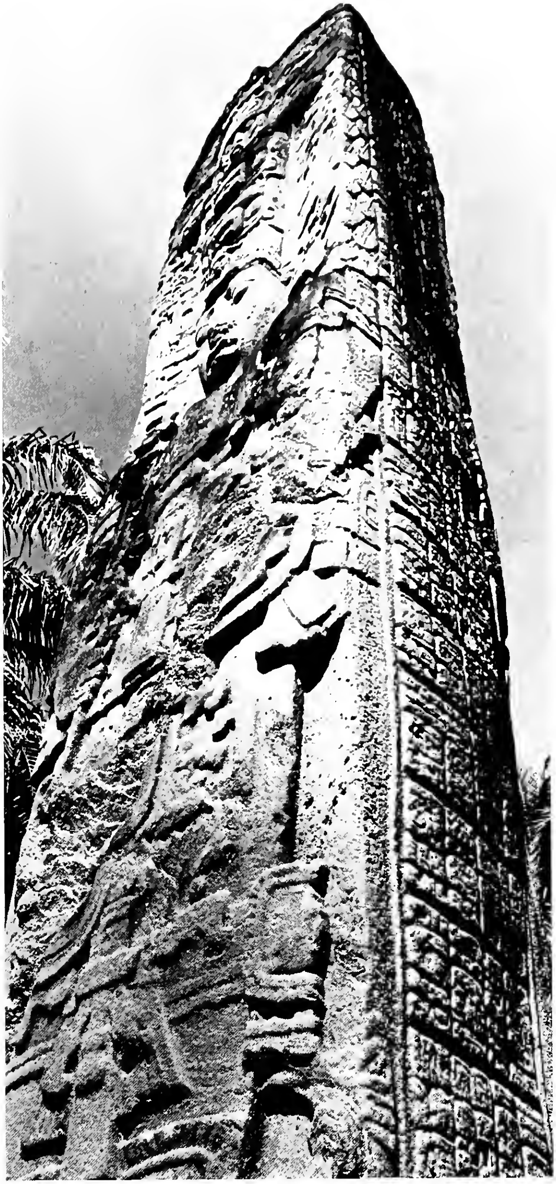

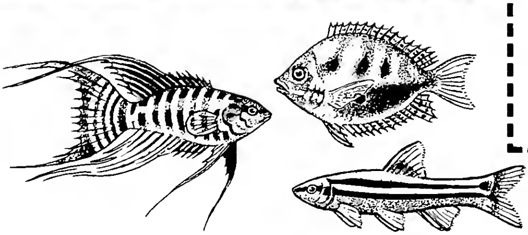

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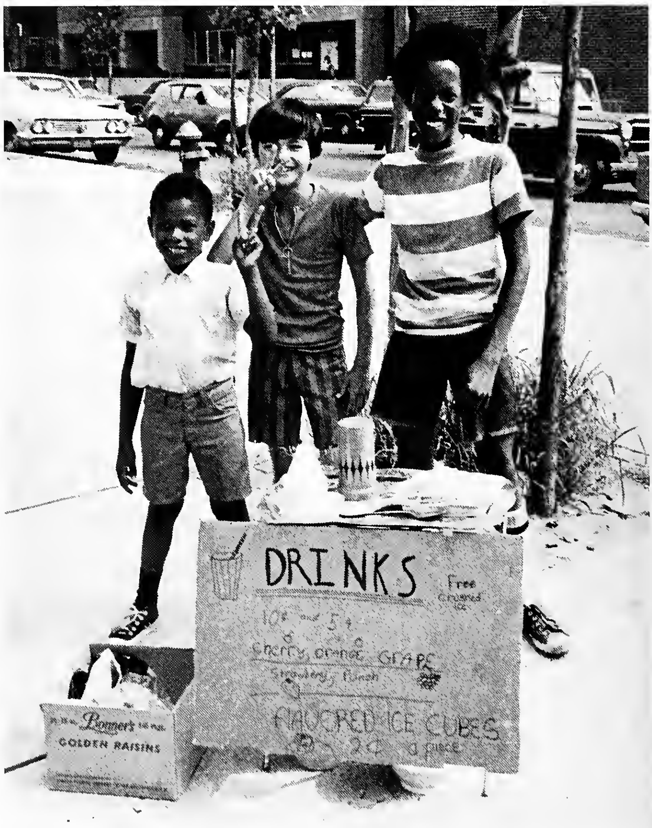

Cold Drink Stand, Manhattan

Beryl Goldberg

uprooting medicinal herbs and plants. It is believed that if one uproots a medicinal herb without any purpose, he will be attacked by the disease the herb is used for. This has developed into a custom, and as a result it is only on rare occasions that one finds such plants being damaged without purpose.

Some animals are saved because they are a sign of good luck to the person who sees them. Many snakes, excluding a few poisonous ones, are left in peace when seen while on a journey. It is believed that they are a sign of a safe journey and, therefore, killing them would be killing one's good luck. This may result in an unsafe journey. A snake that enters a young couple's hut is a sign that they will have a baby. Such a snake is never killed.

Wasps making their mud nests in one's hut are also believed to have the same meaning as a snake. They too are left alone. Should its nest be accidentally broken into fragments in the process of packing the hut up when moving, the pieces of the broken nest and the larvae are collected together and placed in a safe corner. Milk is then poured on for forgiveness.

There is another belief that the killing of one spider attracts many more to the scene. Of course, inviting many spiders by killing one spider is looking for trouble because a person might be bitten. So spiders are left alone.

Another queer fact is that some people are immune to the pain of scorpion stings. It is said that if a scorpion stings a pregnant woman, the baby will never experience any pain from a scorpion sting unless he or she kills it. Once such a person kills a scorpion, his or her immunity to the pain will cease. It is also believed that the intensity of the pain one feels after a scorpion sting depends on the number of scorpions he or she has killed. In fear of this, scorpions are not frequently killed.

Insects like safari ants are considered useful because their presence is a sign of rain. It is believed that if anybody disturbs the long line of the ants, the giver of rains will be annoyed and this may result in shortage of rain. This is another way by which a tribal custom saves wildlife.

Sometimes tribal customs protect the habitat of a species of wildlife. Such customs vary from clan to clan. An example of such a custom is the one which prohibits making a cattle

boma on a place where dik-dik feces (pellets) are abundant. The significance of this custom is not well defined but it has something to do with the well-being of the cattle—perhaps there is a fear of parasitic insects that might be living in the pellets and that can affect cattle. As the Boran tribe is nomadic, the people move from place to place several times every year. It is during these countless shiftings and settlings that this custom works. Frequent interference with any animal habitat can upset their life cycle and can be detrimental to any animal community. Animals like dik-diks and impalas will be forced to take refuge in a new territory. More than this, we still have to consider the less conspicuous creatures that inhabit such an area. These include even the worms that stay in the dik-dik dung.

Settlement very close to a water source is also prohibited—or not liked. This is just a safety precaution from thirsty and often desperate wild animals like elephants and buffaloes which come to drink water. This custom saves wild animals more than the tribe itself, because the advantage is not only gained by the big name animals but also smaller and shy animals like gerenuks, impalas, gazelles, and oryx. Also, children who could disturb the water and the aquatic creatures in it are kept at bay.

Another important custom that saved, and still saves, plant and animal habitats is the one that prevented people from penetrating into a certain area of land believed to be inhabited by evil spirits that had been removed from a person possessed. When a person suffers from some strange illness, a witch doctor is called. After he finds that the person is under the influence of some evil spirit, he takes him or her to a far place away from any home to "curse and chase away" the evil spirit into the bush. This evil spirit is believed to dwell in that place henceforth.

In fear of the spirit, people stop visiting or walking through that area. This area therefore remains quiet, free from any interference by people, and the animals and plants in that area live safely. The particular tree under which the person has been "freed" from the evil spirit is believed to be the actual living place of the spirit, and it is usually fenced all around to prevent strangers from resting under it. Such privacy makes the tree a splendid nesting place for birds. It in-

sures a hundred percent safety of the nests and their contents from man; and such trees are always covered with nests.

From time immemorial, there have been tribal wars and clashes between African tribes, including the Boran. Such wars were waged to raid and take home the enemy's cattle. In the olden days, and in fact even today, bringing home other tribes' cattle after a raid is considered a big achievement for any young man. Every young man yearns for such an achievement to gain tribal distinction. Such raids sometimes result in bloodshed and destruction and mostly affect the people near the tribal border. To avoid this, each tribe retreats and lives far from the tribal boundary.

A good example is the situation between the Boran and Samburu tribes. The boundary between these two tribes passes halfway between Isiolo and Merti towns. Each tribe, in fear of each other, has retreated from the border by as much as fifty miles. As a result, there is a stretch of shrubland about one hundred miles wide devoid of human settlement separating the two tribes. Traveling from Isiolo to Merti, it is common to see herds of elephants, lions, zebras, oryx, impalas, gazelles, and many other kinds of mammals and birds. The animals in this vast land live safely, increasing in population from year to year. This has resulted in the establishment of Shaba-Merti Game Reserve in this area in 1974.

Land in Boran territory is not demarcated and therefore it belongs to the whole tribe. As the tribe is nomadic, they do not value land as they value their animals. Farming, which was introduced only in the last five years, is still considered as dirty and irksome work that does not progress alongside with cattle rearing. Therefore it has been the people's custom to keep and care for animals only. This has saved wild animals and plants in some ways. In farming, the land has to be cleared, cutting down all plants. Wild animals have to be kept away from destroying the crops—often by killing them. Not only are they killed but also their habitat is colonized permanently by man. Therefore, because the tribal customs did not favor farming and land demarcation, they prevented all the above problems from occurring and hence saved wild animals, plants, and their habitats. □

The Fruitful Wasteland

by Denis Hayes

Buried in your garbage are rich fertilizers, electric power, and fuels to cook tomorrow's dinner

For most of human history, the thrifty husbandry of resources was valued highly. Possessions were built to last and were passed on with pride from one generation to the next. Equipment was repaired, clothes were mended. Nothing was thrown away before it had been wrung of all possible use.

The industrial revolution brought an end to this conservation ethic. With the virgin resources of a rich continent to exploit, the United States economic system developed as a one-way process: raw materials entered the economic stream, were processed, used, and quickly discarded. Over the years the debris of our throw-away society has mushroomed into a $6 billion annual problem. Few cities know with confidence where they will dump their trash more than a few years hence. Garbage is becoming a significant energy consumer in the United States. Collecting and disposing of garbage costs more than 5 million Btu for each of the more than 125 million tons we produce each year. (A Btu, or British thermal unit, is the quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit.)

While earlier cultures wisely returned human and animal excreta to the soil, Americans substituted energy-intensive chemical fertilizers. We then either flushed our sewage directly into the waterways or consigned it to sewage treatment plants.

These Stygian waste streams could serve as resource streams. In fact, the organic material that constitutes the bulk of our urban garbage and all of our residential sewage is a rich potential source of energy. Feedlot wastes, agricultural residues, and the by-products of forest industries are other rich energy sources. This energy can be harnessed for human purposes in various ways: direct combustion, anaerobic digestion (feeding the material to methane-producing bacteria), pyrolysis (decomposing the organic matter by baking it at 1,000°F in the absence of oxygen), and hydrogasification (treating the material with hydrogen at a high temperature to form a gas).

After the energy stored in organic compounds has been recaptured, the residue can often be used as a valuable agricultural fertilizer. Our annual production of organic wastes totals about 700 million dry tons, containing more than 11 quadrillion Btu, or approximately one-seventh of our entire national energy budget. Of this, more than one quadrillion Btu is contained in urban garbage.

Opinion differs over the net energy recoverable from organic waste. We must, of course, consider the energy cost of collecting, transporting, and converting waste into fuel. A study for the Ford Foundation Energy Policy Project suggests an upper limit of just over 4 quadrillion Btu, or about 5.5 percent of our total energy budget, on recoverable energy from crop residues, feedlot manure, and urban refuse. This figure, expected to more than double over the next twenty-five years, does not include any of nearly 2 quadrillion Btu of high-quality, accessible forestry wastes. Nor does it allow for the development of biomass-harvesting schemes for growing and processing "crops" solely for their fuel value.

Currently, there is little energy recovery from crop residues. The Hawaiian sugar industry uses the residue from sugar cane, known as bagasse, for fuel and as a component of insulation, but most other crop residues are eventually plowed under. While recent studies have focused on this potential energy source, many claims are overstated. If all crop residues were harvested for fuel, soil fertility and structure would soon be adversely affected. Moreover, the cropland would be prone to erosion. Nonetheless, within limits, some of this energy can be intelligently tapped.

To examine the large-scale generation of methane from feedlot wastes, several experiments are now under way. Era, Inc., of Lubbock, Texas,

is under contract with People's Gas Company to convert 80,000 tons of cow dung into methane each year, and Calorific Recovery Anaerobic Process, Inc., of Oklahoma City, has a similar contract with People's Gas. These two contracts should provide the gas utility with about 100 million cubic feet of methane a month.

Such arrangements are technically possible and economically viable only at large feedlots, but recent grain price rises have led to a substantial decline in the use of feedlots. A more sensible strategy for the long term might consist of range feeding cattle as long as possible and then dispersing them in small herds (up to 1,000 cattle) to grain-region farms for fattening. Their wastes could provide methane for the farm or else be used directly as fertilizer.

About 14 million tons of human sewage (dry matter) are produced in this country annually. While sewage has some potential as an energy source, and is used in India as stock for methane generators, its high moisture content as it emerges from the American sewage system makes such use difficult. In lieu of redesigning our basic approach to sewage, the best use of this material is probably as fertilizer. Substituting sludge for energy-intensive chemical fertilizers conserves energy for other purposes.

The Metropolitan Sanitary District of Chicago (MSD) has pioneered in the use of sludge as an agricultural nutrient in this country. MSD sludge has proved to be a valuable nutrient material for strip-mine reclamation. The MSD's reclamation project in Fulton County, Illinois, applied sludge to about 3,000 acres of ravaged land in 1975. MSD pays real estate taxes on this property and hopes eventually to restore about 40,000 acres of strip-mined land to agricultural productivity.

There is one problem, though. Since industrial wastes and human sewage are usually blended in common lines, sludge used as fertilizer may contribute to a buildup of poisonous heavy metals common in industrial waste.

There are three techniques for direct application of sewage on land. The first is to heat raw sewage to about 1,400°F until the water has evaporated, leaving a granular substance. This produces a high-grade fertilizer that is in great demand, but the process is highly energy-intensive and expensive. A second approach is

to pile up the sludge and let it dry in the air for a period of years. The final method is digestion for about fourteen days at 95°F, producing a liquid containing about 4 to 6 percent solids. This sludge can be sent by barge, pipeline, or rail to agricultural land.

The energy for these processes can be obtained from digester gas—a mixture of methane and other gases given off from heated sewage. Until forty years ago, when cheap natural gas was substituted for this somewhat corrosive fuel, sewage plants were often powered by digester gas. Now that natural gas prices are climbing, digester gas is staging a comeback; in southern California it has fueled some sewage plants for a decade.

The energy-recovery process most widely used today is the production of electricity from urban refuse. Since trash disposal is a major nationwide problem, cities can afford to pay a premium for energy-generating processes that reduce the volume of residual waste. Although urban trash lacks the consistency of agricultural refuse or feedlot wastes, it has a low sulfur content and a caloric level competitive with much coal.

The practice of mixing garbage with other power-plant fuel in order to reduce solid waste volume, recover useful energy, and lower the average sulfur content of fuel has been common for a half century in Holland, Paris, and Copenhagen. Several areas here are now using it as well.

Milwaukee has begun construction of a plant to handle the entire city's garbage. The plant will collect aluminum, steel, and glass, and provide supplemental boiler fuel. Saint Louis, which has been experimenting with energy recovery from garbage since 1972, has committed itself to a $70 million plant that will burn shredded garbage with pulverized coal to produce electricity. Connecticut has begun a $250 million, ten-plant project to convert 84 percent of the state's solid waste into 10 percent of the state's electricity.

Even the Tennessee Valley Authority is studying a means of obtaining about 7 percent of its power from garbage. A $35 million plant in Saugus, Massachusetts, burns garbage from about twelve towns, producing steam that is then sold to a nearby General Electric plant.

Even though it generally requires more energy to refine virgin ore than to recycle scrap metal, several million tons of refined metal go out with

the garbage in America's cities each year. At least 7 million tons of iron, 400,000 tons of aluminum, and 100,000 tons of copper could be economically recovered and recycled, with a net savings of about 400 trillion Btu. This excludes metals found in building demolitions and scrapped automobiles. About 6 million automobiles are retired annually, and the average car now on the road contains well over 3,000 pounds of ferrous metals and 50 pounds of aluminum. Assuming that two-thirds of this metal can be recovered and recycled, 6 million tons of iron and 100,000 tons of aluminum, as well as about 300 trillion Btu, would be saved. Using existing technologies, about 1 percent of our national energy budget can be saved by metal recycling.

The practical objection to a growing national commitment to energy extraction from waste is that we may develop a vested interest in unnecessary waste. Avoiding an unneeded wrapper is clearly preferable to throwing it away and recovering its energy potential through incineration. Using standardized, returnable glass containers is clearly better than using one-way cans—even if the metal from the cans is recycled. In France a recent report by the minister of commerce notes, "It is preferable to incorporate energy and raw materials in an object that lasts a long time rather than manufacture a dozen things to be thrown away almost immediately." The report calls for high taxes on goods with short life-spans, including all packaging, and would require manufacturers to supply spare parts for their products.

The best approach is to save energy directly, by eliminating some of the bulk in our solid waste. Archeology students in Tucson, Arizona, recently excavated fresh municipal garbage and calculated that between 10 and 15 percent of all food was thrown away. Since the energy value of the fuel used to grow, harvest, process, retail, transport, and prepare food is several times greater than the food's caloric value, we would obviously do better to consume the food (or cut production) than to recover its energy in a utility boiler.

Even if we return to our ancestors' conservation ethic, societies will always generate streams of waste. We must recapture what we can of that waste and put it to use again for human benefit. Proverbially, wasting less may mean wanting less. □

Kwakiutl Cuisine

A simple larder did not suppress the culinary impulse of Indian women

Faithful readers of this column will recall several harangues against the anthropological community, damning it for its neglect of food in the cultures it studies. I should have lumped myself and other food writers in the indictment, for we also turn up our pampered noses at the wealth of ethnographically interesting cookery still practiced in native American kitchens across the land.

Even at a time like this, the eve of the first Thanksgiving of the first year of the country's third centennial, you will read only passing, and most likely condescending, references to the crucial Indian contribution to our national feast. Food editors gabble glibly enough about Squanto and the lesson in organic fertilization he gave to Pilgrims breaking ground for their first corn crop. And when white American gastronomes really want to bear down in earnest on the early history of their subject, they trot out a conveniently short list of Indian dishes that some non-Indians still eat: succotash, filé gumbo, Indian pudding, hominy, and the seafood steamed in seaweed at clambakes.

In a way, these cursory tributes amount to a respectable enough homage. They show as much knowledge of, and reverence for, national culinary origins as, say, French epicures exhibit toward their folk cuisine of the eighteenth century. What is more, we can boast (as I have recently learned from David Brose, an anthropologist in Cleveland) of at least one extraordinarily thorough American monograph on the food of a North American Indian people.

George Hunt, a "mixed-blood" Kwakiutl of Fort Rupert, British Columbia, collected data on all aspects of Kwakiutl life at the beginning of this century. Hunt was a protégé of Franz Boas, the father of American anthropology, and he was fluent in the Kwakiutl language. His research was published as a long paper, edited by Boas, in the thirty-fifth annual report of the Bureau of American Ethnology (dated 1913–14, but printed in 1921 as "Ethnology of the Kwakiutl"). Hunt seems to have gathered his data verbatim from local informants among the roughly 2,000 Kwakiutl speakers still living in more or less the traditional way on Vancouver Island. He was helped in this task by Mrs. Hunt, who, as Boas put it in the preface, "was born in Fort Rupert, and who was thoroughly familiar with the duties of a good housewife " in those days.

The result is a trove of hundreds of pages of transcript (printed in English and Kwakiutl) of directions for preserving food and of recipes for cooking it. The Hunts and Boas captured the life of a vanishing civilization in the most concrete way possible—through its food.

The recipes meticulously record a whole galaxy of solutions to the problem of survival in the Pacific Northwest. The Kwakiutl were fishermen and foragers, but the simplicity of their larder and their technology did not limit them to uncomplicated cookery. Modern salmon lovers will feel profligate when they read the intricate description of what the Kwakiutl women did with salmon tails and backbones, tying them two at a time by the tails and hanging them close to the fire just under the salmon flesh, which was also slowly drying. Eventually, they separated the smoked tails from the backbones and stored them both in special cedar-bark baskets for eventual soaking and eating in winter.

Equally specific instructions were necessary for splitting and preserving the flesh of the dog salmon. It had to be cut away from the backbone down to within "four finger-widths from the place where she broke off the salmon's tail." The backbone was discarded, leaving a Y-shaped double fillet joined at the "tail-holding-

together." This configuration was hung tail-end down for three days and then tail-end up for three days. There ensued various other stages of boning and rubbing and hanging. Eventually the "tail-holding-together" was split off and stored separately from the fillets, which were called, collectively, the "split-down."

Kwakiutl cookery lacked a sophisticated spice shelf; indeed, it lacked spices altogether, unless we count the salt of seawater and the natural sugar of berries. Nevertheless, the Hunts' recipes show the culinary impulse at work. The Kwakiutl palate must have relished taste and texture differences between those separately stored tails and backbones and fillets of salmon. And we may assume that connoisseurship entered into their cuisine as it does in ours, with certain cuts and portions holding pride of place. This certainly was the case with seal heads, which were the prerogative of steersmen and chiefs. They were bartered at the rate of five pairs of blankets for 100 heads. And chiefs reserved these heads for old people, who ate the blubber on them. It was boiled for a long time, removed with tongs, and eaten in strips with dried salmon or halibut.

Many of these recipes are of no current use. Our chiefs have no seal heads to pass along to senior citizens. Few of us would consume eelgrass or even clover, either for pleasure or out of curiosity. No doubt, this is a mistake, a sophisticated error. We do, however, still value the marvelous savor of salmon when it is grilled in the manner of the Indians of the Northwest (a method also recorded by the Hunts), which is to say, attached to wood tongs set upright at the side of a campfire.

Perhaps even salmon guts and some of the other more exotic-sounding recipes of the Kwakiutl would delight us if we tried them. "Flounder eaten with spoons" might be a good place to start. It consists of flounder eaten with the water in which it has been boiled, with a little oil added. The flounder is cleaned and then boiled whole until its flesh will break up when it is stirred in the pot. This dish is somewhere between a fish chowder and fish cooked in a court bouillon, or flavored liquid. And if we could find as fresh a flounder as the Kwakiutl could, it might make an acceptable fish dinner.

All the same, I do not think the value of the Kwakiutl study rests on

its popular acceptance by practicing contemporary cooks. For one thing, they would wear themselves out gathering kelp and weaving baskets for blubber. But even if no one ever cooks anything from this encyclopedia of "primitive" cuisine, the work was worth the trouble because it shows, in a way everyone can appreciate, how diverse and imaginative and joyful tribal life could be. More specifically, it shows that Indians, with a cuisine limited to a very small number of raw materials and techniques, construed their gustatory processes in terms as rigorous and scientific as any modern home economist.

In our own "advanced" food culture it has taken centuries of fumbling and inaccuracy to arrive at a style of recipe writing that is clear and that will enable the neophyte to duplicate the results of the expert writing the recipe. Home economists perfected modern recipe style in the United States in this century. Before them, cookbooks were essentially *aide-mémoires,* without specific quantities or cooking times or instructions for finding and dealing with ingredients. There were exceptions of a sort, but generally speaking, to use cookbooks published before the First World War, you had to proceed by guess and by gosh. Either the authors were chefs writing handbooks for other chefs or they were casual amateurs.

The famous *Boston Cooking-School Cookbook* by Fannie Farmer (first edition 1896; modern facsimile published in paperback by Plume) was an early attempt at scientific recipe writing. The dishes had all been tested by the author and they were supposed to be reproducible in the average home, just as scientific experiments can be reproduced in laboratories.

Mrs. Farmer's recipes do list measured amounts of flour and other ingredients and they are fairly clear. Her touch with foreign recipes is unsure (did she really whip egg whites for omelets?) and she did love canned vegetables. But her triumph was to anticipate most of the questions cooks would ask themselves. Today we have gone even further, and such masters of explication as Julia Child have sometimes anticipated more puzzlement than normally ever exists. But the most extensive expatiations of Mrs. Child do not exceed in elaboration the orderly expositions of the Kwakiutl women interviewed by the Hunts. They knew what you had

to do, from gathering wood to washing your hands when the meal was over. They calmly laid out their whole homely technology, step by step, without a stutter of imprecision, except perhaps to add, parenthetically, what to do with hanging salmon when the weather threatened rain. (Move it indoors.) And they were fine storytellers, even if they did indulge the vice of repetition so heavily that Boas complained of it. But these Kwakiutl cooks had never heard of a cross-reference. And many modern cookbook writers would be better off if they were as repetitious and did not send us flipping around madly for a missing step partially expounded in each of three previous pages.

The Kwakiutl were nothing if not straightforward. Here for example, is an excerpt from the Kwakiutl recipe for roasted salmon:

> Now I shall talk about the salmon speared at the mouth of the river when it is still phosphorescent. When the man who spears the salmon gets one, he goes home as soon as he has speared it. His wife at once takes an old mat and spreads it over her back; then she takes her belt and puts it on over the old mat on her back. Then she takes along a large basket in which to carry the dog salmon on her back. She goes to the canoe of her husband and puts four dog salmon in her carrying basket. Then she goes up the beach to the place where she is going to cut them. She puts them on an old mat, which is spread on the ground outside the house. As soon as she has thrown them on the ground, she takes her fish knife and sharpens it; and after she has sharpened it, she cuts off the gills of the dog salmon. . . .

And so on for two and a half more pages of cleaning and roasting, complete with directions for entertaining guests and the sensible suggestion that it is unwise to eat salmon speared at the mouth of the river in the morning, because "it makes those who eat it feel sleepy the whole day long, for it is very fat." Finally, feminists will be glad to hear that the Kwakiutl husband cleaned up when the feast was over: "He gathers the bones and the skin left by his guests, puts them on a mat, and throws them into the sea on the beach. This is all about the salmon speared at the mouth of the river." And this is all about Kwakiutl cookery, except for a wistful, back-

ward glance and a terse, but practical, modern American version of grilled salmon for home use at any time of the year and at any meal other than breakfast.

Grilled Salmon

4 salmon steaks, about 1 inch thick
Oil
Salt and pepper

1. Preheat broiler.
2. Oil the steaks and the surface of the broiling pan.
3. Put the steaks in the pan and run under the broiler about 2 inches from the heat source. If you are doing this over charcoal, oil the top of the grill and arrange it so that the fish will be two inches from the coals.
4. Turn the steaks carefully after five minutes. Cook another five minutes or until the flesh is flaky. Season to taste with salt and pepper. Do not throw leftover skin and bones in river or ocean.

Yield: 4 servings

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*

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Ah, Wilderness!

WOODSWOMAN, by Anne LaBastille. *E. P. Dutton & Co., $10.95; 277 pp., illus.* A WORLD OF MY OWN, by Mike Tomkies. *Reader's Digest Press, $10.95; 273 pp.* THE YEAR-LONG DAY, by A. E. Maxwell and Ivar Ruud. *J. B. Lippincott Company, $8.95; 240 pp., illus.*

Three books, three lives. A book is an offering. "Here is my life," the author says, "take it." Take me. Take me to your heart. Or, take me apart. (Critics feed on art; the fresh new author is the reviewer's favorite breakfast food. The critic-reviewer is to the book as the orchid is to the tree: a parasite.) If more authors understood how nakedly they reveal themselves in the writing of a book, there

Anne LaBastille

by Edward Abbey

would doubtless be not so many books. The egocentric exhibitionist is, of course, the most pathetic case of all. Behind every book lies the author's belief that his life, her life, or some part of it, is of such importance that it must be of interest to us all. Such audacity and innocence. But justified. I cannot conceive of any human life that, fully described from within, would not be of totally absorbing significance. The clerk-typist at Time-Life, the shopgirl at Woolworth's in Melbourne, the fellow who figures out what's wrong with your Volkswagen (sometimes correctly)—each leads a life as intricate, strange, mysterious, rich, and terrible as the world itself; indeed, each life *is* a world in itself. Transmuting that private world into a coherent world of words, however, is a difficult operation. Generally speaking, it is impossible.

The three books here under review are modest endeavors. None makes any pretense at the creation of a world. Each in its own way, with varying degrees of success, reports on a kind of personal achievement that appeals to a fantasy most of us have entertained but lack the gumption to make real. LaBastille and Tomkies went out in the woods and built themselves log cabins—habitable homes. Ivar Ruud lived the life of hunter and trapper in the Arctic, skiing back and forth between two cabins. Each of the three sought freedom, self-sufficiency, independence—ideals that, in the more-or-less real world of today, seem as fantastic as any other dream.

Of the three, Anne LaBastille appears to have come closest to establishing her relative independence on a workable, permanent basis. In *Woodswoman* she tells how she discovered and fell in love with the

"North Woods" of the Adirondacks, how she found a place of her own, built a cabin on it with a little help from friends, made a home. A professional ecologist and journalist, she earns her income and subsistence from the world "outside," but her cabin and 22 acres on the shore of a lake she wisely leaves unidentified provide her with the substantial home base that every human needs. (Even R. Buckminster Fuller with his armload of wrist watches and global credit cards would be lost without the firm footing of a Boeing 747.) LaBastille recounts her love affairs with trees (of how it is possible, for example, to draw strength from a good spruce tree by embracing it; in this she is absolutely correct, I'm sure, though I'm a bristlecone pine man myself), with the birds and animals of her elected place, and with men. Forced to choose between her home and her lover, she gives up the man. This choice, lightly touched on in the book, is nonetheless moving to the reader. She defines the good life as consisting of health, work, and love. Though familiar with loneliness, she wants the love on terms compatible with her way of life. The world changes. One must respect her courage and wish her good luck. I shall permit myself just one minor critical outrage: with so open and vulnerable a book it would be *ungentlemanly* to point out flaws.

Mike Tomkies is or was an Englishman. Or is it impossible to be an ex-Englishman? No matter. At least

Mike Tomkies

he does not write like an Englishman; he writes like a Canadian. His book, *A World of My Own,* is subtitled *Adventure and Personal Renewal in the Wilderness*. Okay. According to Mr. Tomkies he was a highly successful journalist in England and Europe, jostling elbows and spilling drinks with "the rich, the illustrious, the swift" in London, Paris, Rome, Madrid. And then, suddenly, at the age of forty (like Henry Miller), he gave it all up in disgust, including the glamorous women, homesteaded a few acres on the rockbound coast of British Columbia, and built himself—a log cabin. With the help of a neighbor, in this case a wise old ex-logger and carpenter with quaint speech mannerisms: " 'Hoysters are good for you,' he said emphatically. . . . 'Hoysters, heggs and honions!' " Once he gets a roof over his head the ex-journalist sits down to complete his novel, while the northwest rains pour down all winter long on his shake roof. Suffering from loneliness, he falls in love with a dog. His novel is rejected by four different agents. Not publishers, *agents*. Naturally dejected, he goes off to watch grizzly bears with another crusty old character, Pappy Tihoni, the locally famous Indian, who turns out to be a bigger windbag than Carlos Castenada's Don Juan. Pappy Tihoni talks like this: "Laddie, one can love humanity only when one is not too closely involved with it, because then it becomes a huge, tragic-comic joke." And so on. Was it Chekhov who said, "There is no bore like the provincial celebrity"?

But this is not a bad book. Despite the clichés that keep raining down, like the skies of British Columbia, the author's earnest accomplishments compel admiration, while some of his wilderness adventures, as reported, have the ring of plausibility. At the end of the book, Tomkies, his spirit renewed and refreshed, announces his readiness for a return to "what is loosely called civilization." He doesn't say where he is going next but I can guess: Los Angeles.

The Year-Long Day: One Man's Arctic is a work of collaboration between three people: Ivar Ruud, a young Norwegian who lived for six years on Norway's Spitzbergen Island in the far North, and Ann and Evan Maxwell, professional free-lance writers and journalists. The year-long day of the title refers, of course, to the prolonged days and

Ivar Ruud

nights of the Arctic summer and winter.

Mr. Ruud's life in the Arctic was arduous, adventurous, and hazardous. The book describes his work as a trapper of foxes and as a hunter of ducks, geese, seals, bears. He travels by boat, by skis, by dog team. He survives blizzards, storms at sea, the loneliness and boredom of the long, dark winters, and several hair-raising encounters with polar bears. The constant struggle with cold and wind strikes me as a miserable way to make a living, but Mr. Ruud found it to his liking and would be there yet, he tells us, on that bleak and ice-covered island, if the Norwegian government had not closed it to hunting and trapping. The book is illustrated with striking photographs by the protagonist; the pictures of polar bears are especially impressive. Mr. Ruud now lives in Los Angeles. Can't blame him.

Three modest books, as I said. But the lives they portray, the nerve and the daring they reveal, can only inspire in most of us, slothful dreamers that we are, feelings of respect and envy.

Edward Abbey is the author of The Monkey Wrench Gang, *a novel, and several other books.*

Additional Reading

Spirits of the Dead (p. 12)

Several autobiographical accounts of field anthropologists' experiences, which have appeared in *Natural History* are collected in part 3, "On Natives and Naïveté," of *Ants, Indians, and Little Dinosaurs* (New York: Charles Scribner's Sons, 1975, $8.95). Hortense Powdermaker's *Stranger and Friend: The Ways of an Anthropologist* (New York: W.W. Norton & Company, 1966, $2.65) gives accounts of field work in four diverse cultures. *The Savage and the Innocent,* by David Maybury-Lewis (Boston: Beacon Press, 1968, $2.95), recounts his expedition to central Brazil and the effects of mutual misinterpretations, distrust, and other difficulties on his studues. Arnold Schneebaum's *Keep the River on Your Right* (New York: Grove Press, 1969, $1.95) is a powerful tale of self-discovery while living among a previously undiscovered tribe in Peru. *Tristes Tropiques,* by Claude Levi-Strauss (translated by J. and D. Weightman, New York: Atheneum Publishers, 1974, $3.95), provides insights into the author's feelings during an anthropological and intellectual odyssey to South America.

White-tailed Kites (p. 40)

Two sources of background information on kites and their place among the other raptorial birds are Leslie Brown and Dean Amadon's *Eagles, Hawks, and Falcons of the World* (New York: McGraw-Hill Books, 1968) and Arthur Cleveland Bent's *Life Histories of North American Birds of Prey,* published in 1937 as part of a monumental 23-volume series on the natural history of our avifauna and now available as an inexpensive reprint (New York: Dover Publications, 2 vols., 1958, $4 each). "Natural History of the White-tailed Kite in San Diego County, California," by J.B. Dixon et al. (*Condor,* 1957, vol. 59, pp. 156–65), reports on a long-term study of nesting, communal roosting, and other aspects of kite behavioral ecology. "Range Expansion and Population Increase in North and Middle America of the White-tailed Kite (*Elanus leucurus*)," by Eugene Eisenman (*American Birds,* 1971, vol. 25, pp. 529–36), describes the species' ecological adaptations and its response to habitat changes. "Recovery of the White-tailed Kite," by

Donald R. Fry, Jr., (*Pacific Discovery*, 1966, vol. 19, pp. 27–30), discusses a study of one large roosting population in relation to game management problems. Lee Waian and Rey Stendell's "The White-tailed Kite in California, with Observations of the Santa Barbara Population" (*California Fish and Game*, 1970, vol. 56, pp. 188–98) gives further details of the kite studies described by Waian in his present article.

The First Gorilla (p. 48)

George B. Schaller's *The Year of the Gorilla* (Chicago: University of Chicago Press, 1964, $2.95) recounts his years of careful field work and his discoveries on the behavior and ecology of the mountain gorilla—many of which dispel the myths surrounding this giant ape. Carl E. Akeley's early attempts to study the gorilla in the wild are described in the September-October 1923 issue of *Natural History* ("Gorillas—Real and Mythical," pp. 428–47). Gorilla mythology may be traced through Ramona and Desmond Morris's *Men and Apes* (New York: McGraw-Hill Books, 1966) and W.C. McDermott's *The Ape in Antiquity* (Baltimore: Johns Hopkins Press, 1938). Paul B. Du Chaillu's *Explorations and Adventures in Equatorial Africa* (1861) was perhaps the greatest generator of misinformation concerning gorillas in the wild. It has been reprinted a number of times (for example, by Negro Universities Press, Westport, Connecticut) and should be available in many libraries. Two recent books dealing with the great apes and gorillas are *The Apes*, by Vernon Reynolds (New York: Harper & Row, 1971, $3.45), and *The Gentle Giants: The Gorilla Story*, by Geoffrey H. Bourne (New York: G.P. Putnam's Sons, 1975).

Energy from Waste (p. 96)

Wilson Clark's *Energy for Survival: The Alternative to Extinction* (New York: Anchor Press, 1974, $4.95) deals with a wide range of energy technologies—from conventional sources (oil, gas, coal) to the more esoteric (nuclear, solar, wind, tides, ocean currents). *The Energy Conservation Papers*, edited by physicist Robert H. Williams (Cambridge: Ballinger Publishing, 1975), brings together six seminal studies of energy conservation strategies, including one on energy from organic waste. Harold H. Leich's "The Sewerless Society" (*Bulletin of the Atomic Scientists*, November 1975, pp. 38–44) describes "a quiet revolution in disposal methods," including alternatives to the ubiquitous flush toilet. *A Time to Choose: America's Energy Future*, by the staff of the Energy Policy Project of the Ford Foundation (Cambridge: Ballinger Publishing, 1974, $3.95), is the final report of a multimillion-dollar study of the growth in U.S. energy consumption.

Gordon Beckhorn

Announcements

A permanent exhibition, the first of its kind in the world—**The Hall of the Sun**—will open at the American Museum-Hayden Planetarium in late November. The hall's exhibits, created through models, graphics, and lighting, will explain the sun's role in the universe and its influence on our daily lives. Visitors to the hall will first enter a red- and orange-hued gallery where they will learn how the sun influences climate, how it creates wind and produces food, and how its energy can be utilized. Using levers and wheels, visitors will be able to manipulate many of the exhibits. The hall's second gallery will explain the sun's role in the universe. Rotating models of the sun and earth at either end of the gallery will show the comparative sizes of these two bodies. A laser beam encased in lucite and running between the two models will mark off their distance from each other. Exhibits using lighting reflected in mirrors will simulate the surface and interior of the sun. Other exhibits will explain the sun's energy capacity and its history. The hall will also have a small theater where continuous films will be shown.

At the **Hayden Planetarium** of the Museum, "Follow the Sun" will continue through November 29. This Sky Show explores the nature of our nearest star, its source of energy, the changes it undergoes, some of its influences on earth, and its place in the universe. Ancient societies worshiped the sun and followed its motion, often performing elaborate rituals in an attempt to gain some control over its activities. Today, astronomers follow the sun hour-by-hour with sophisticated solar instruments and record outbursts of magnetic storms, giant eruptive prominences, and violent solar flares that send large amounts of radiation into space.

Architect's model of The Hall of the Sun

Shows begin at 2:00 P.M. and 3:30 P.M. on weekdays, with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children and students (special rates for groups and senior citizens).

The following **Field Study Tours** are scheduled for 1977.

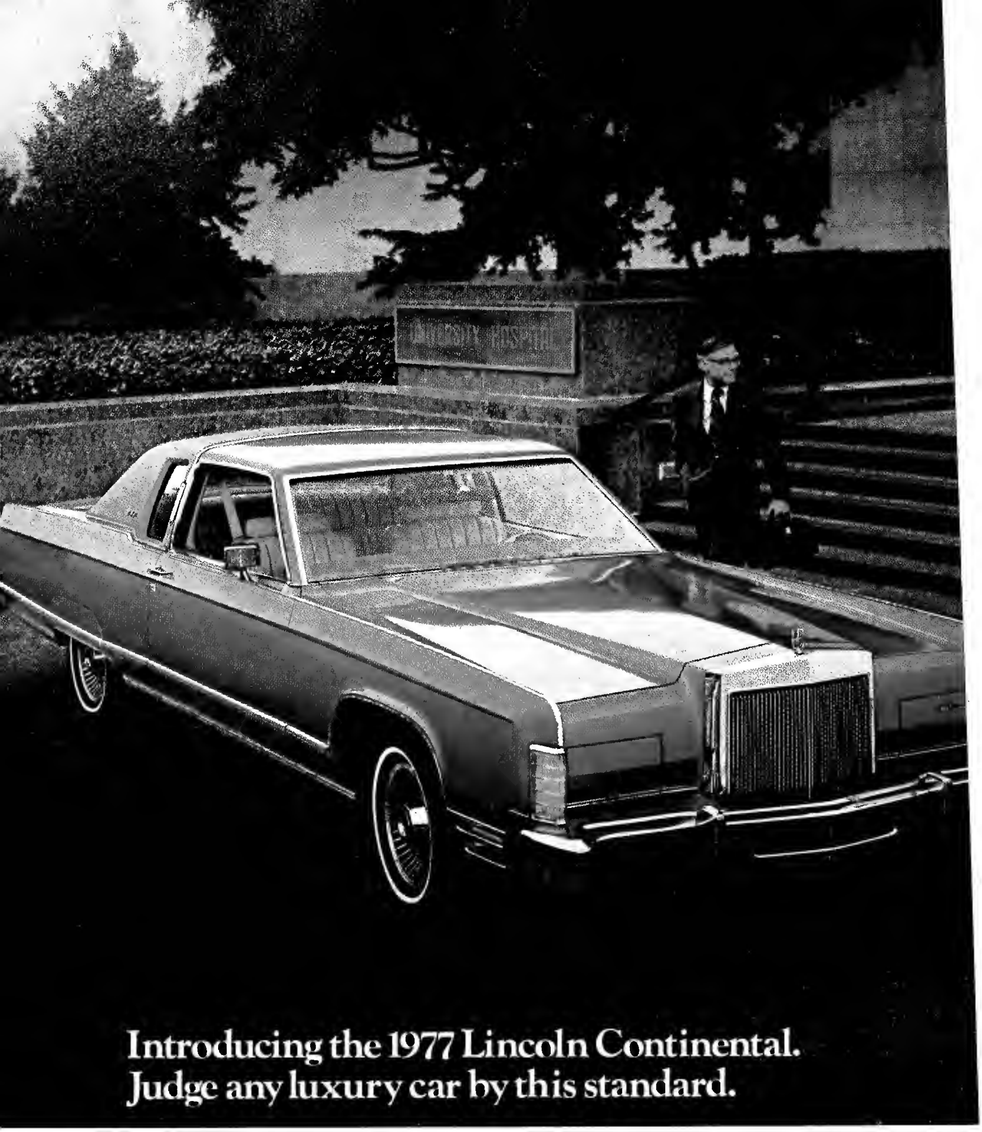
Anthropology Tour to Morocco—A journey through Moroccan cities and countryside to the famous medieval city of Fes, the souks of Marrakech, the camel markets at Sijilmassa, and into the Sahara Desert; visits will be made to Berber villages and to archeological sites and museums in Tangier, Rabat, Roman Volubilis and Lixus.

Geology Tour of Iceland and Greenland—Iceland, a land of ice and fire that straddles the Mid-Atlantic Ridge, continues to be reshaped by crustal movements, volcanic activity and glaciation. Greenland has some of earth's oldest rocks as well as North America's largest single ice mass. Visits will be made to Eskimo coastal villages.

Other tours are Archeology Tour to Mexico, Archeology Tour to Maya Mesoamerica, Archeology Tour to South America, Wildlife Tour to Alaska: Giant of the North, East African Geological Safari, Field Geology of the Grand Canyon, Weekend Field Trip for Bird Enthusiasts, and Weekend Field Trip in Geology. For details on fees and dates write to Museum Tours or call 873-7507.

The **Special Gem Exhibit** of the Hall of Minerals and Gems on the first floor of the Museum has been extended through November. On display are the Tiffany Diamond, the Eugenie Blue, the Zale Light of Peace, and three new additions: the Bicentennial Diamond Necklace, crafted in 1776 by order of George III of England, which contains nearly 500 diamonds totaling 330 carats; the Flaming Star, a flawless, exceptionally rare pear-shaped diamond, which weighs 18.52 carats and fluoresces with a vivid red glow; and the Golden Hope, a naturally-colored, cushion cut yellow diamond weighing 44.35 carats and set in a diamond, gold, and platinum pin.

Note: The main auditorium of the Museum will be closed to the public through January 1977. Weekly film programs will be held in the Education Hall on the first floor.



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NATURAL HISTORY

Incorporating Nature Magazine
Vol. LXXXV, No. 10
December 1976

Cover: *Its nuptial crest feathers and the "horn" on its bill signify that this North American white pelican is in breeding condition. Photograph by Herbert Clarke. Story on page 48.*

Publication Office: The American Museum of Natural History, Central Park West at 79th Street, New York, N.Y. 10024. Published monthly, October through May; bimonthly June to September. Subscriptions: $10.00 a year. In Canada and all other countries: $12.00 a year. Second-class postage paid at New York, N.Y. and at additional offices.

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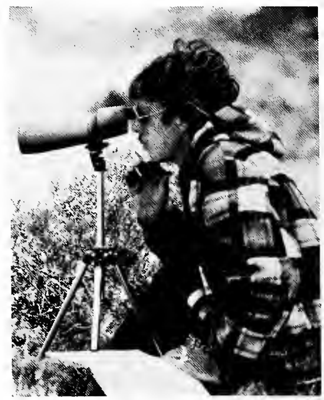
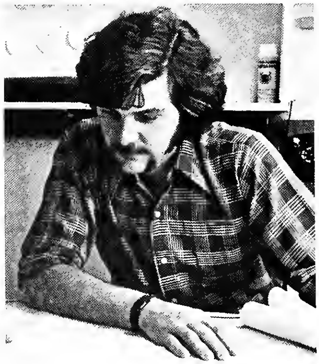
Authors

While sailing his sloop in the Caribbean in 1970, **Horace Beck** discovered that smuggling, a predominant activity among the islanders, was closely tied to their folklore. Beck, who teaches American literature at Middlebury College, has researched maritime folk cultures for more than 30 years, sailing along the coasts of New England, eastern Canada, and west Africa, as well as several European countries. His love of sailing has brought him into close rapport with the people of maritime societies, who are often well versed in their native folklore. Beck's next project will be a comparison of indigenous whaling methods at Saint Vincent in the West Indies with those of the Tonga Islands of the South Pacific.

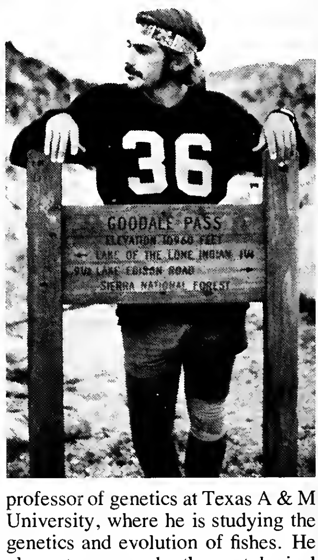
The decline of the brown pelican—mainly because DDT weakened its eggshells—first raised **Fritz L. Knopf**'s concern about these large water birds. When he found that little was known about general pelican biology, he began a study of the natural history of white pelicans. At present he is investigating the food habits and foraging sites of both pelicans and cormorants at Pyramid Lake, Nevada. Knopf, an assistant professor in the Department of Ecology at Oklahoma State University, also plans to do a comparative study of ecological relationships of pronghorn antelopes in short- and mixed-grass prairies. His avocation is photography.



Craig Morris became interested in the vast network of Inca roads and cities while researching the complexity of Inca storage facilities for his doctorate in anthropology. He began to study Huánuco Pampa, one of the largest settlements, in 1965. Now a curator of South American archeology at The American Museum of Natural History, Morris estimates that his research on Huánuco Pampa will take at least three more years of sorting, classifying, and cataloging. Besides unraveling the details of Inca organization, Morris likes to cook, renovate old houses, and listen to classical music while working in his laboratory.



Marine botanist **Henry W. Moeller** discovered the wreck of the *Culloden* entirely by accident. Part of his work as a researcher at the New York Ocean Science Laboratory in Montauk, Long Island, is to assess the potential of growing Irish moss on a commercial basis. While skin diving off the tip of Long Island in search of varieties of the plant, Moeller happened to spot some of the ship's timbers lying on the sea bottom. A teacher at Dowling College in addition to his duties at NYOSL, Moeller's avocation is marine archeology and Long Island marine history. In pursuing his hobby, he has sighted a dozen wrecks. **Steven A. Giordano,** a marine technician at NYOSL, has assisted Moeller with both his seaweed experiments and his archeological interests.



Margaret F. Gold worked with her husband, John, in the Little Kern River basin of California's Sierras, collecting specimens of golden trout and doing general surveys of the fish populations and the physical characteristics of trout streams in the area. A naturalist, Gold spent this past summer completing a field study on the ethology of the Belding's ground squirrel. **John R. Gold** is an assistant professor of genetics at Texas A & M University, where he is studying the genetics and evolution of fishes. He plans to research the cytological aspects of speciation in North American freshwater fishes and the systematics and evolution of Pacific Northwest trouts. From 1973 to 1975, he investigated hybridization between endemic golden trout and introduced rainbow trout in the Sierras.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A Native Replies

by John L. Gwaltney

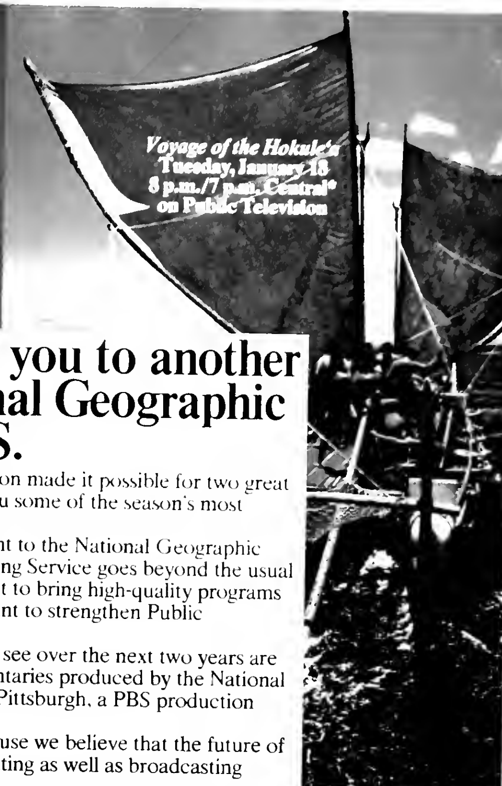
If any hearts and minds are to be won, anthropology must accept a diversity of views

> The native replies to the living lie of the colonial situation by an equal falsehood.
>
> *Frantz Fanon*

I was certainly born a native of the natives as a kindly fortune saw fit to deposit me in a great, extended Black American family. Like most people, I suppose, I felt that I had been fortunately situated by the great god chance. The only disadvantages I was sensible of as a child were those that were the necessary consequence of blindness. It was to minimize this disability that my mother, who held the portfolios for defense and foreign relations in our family, initiated a lengthy exchange with the demon officialdom. Eventually these negotiations reached White House level as our "first lady" believed Eleanor Roosevelt to be a member of a pitifully small company for whom a Caucasoid status had not proven to be an insurmountable moral impediment. All this summitry culminated in the decision to dispatch me to what were then known as sight-saving classes. Because such classes were conducted in schools located beyond the boundaries of my Casbah, my formal education involved an inordinate amount of dealing with foreigners.

In school I learned, among other things, how White people distort history—and then I came home and learned, among other things, how Black people distort it. Much of what I learned in school was not designed to reinforce my conviction that I had been born at least as well as anyone else, but those worthy and reverend Black elders who were quietly intent upon the forging of my soul drew me out with such consummate grace that the hurt sustained by my native mind was often assuaged before I was fully aware of the pain. It did not require much time or sagacity to arrive at the sacred conclusion that native (Afro-American) and settler (Euro-American) views on almost any issue of substance, not to mention a Fundy tide of trivia, were diametrically opposed. I cannot recall a time in my conscious existence when I was not aware of an astronomical dichotomy between "the people," my people, Black people; and Buckra, Charlie, or "the Man."

More than the shadow of this schism had been cast upon my preschool consciousness by the most reverend of those Black elders, my paternal grandfather, who was a sagacious, self-taught classicist and Hausa scholar whose equanimity, integrity, and encyclopedic knowledge made him the leader of a large kindred. He, like most Black elders I knew, held privately but tenaciously to the view that White people were genetically incapable of the broad process of civilization. He did not question the Caucasoid capacity as a perfectly adequate tribe of smiths and tinkers, but he did entertain formidable reservations about the ability of White men to use the strange and awesome fruit of their forges with anything like wisdom and deliberation. The existence of individuals and groups that seemed to validate Caucasoid pretensions to more than purely mechanical sufficiency was attributed to the antiquity and pervasiveness of the practice of "passing" or charged to that reprehensible



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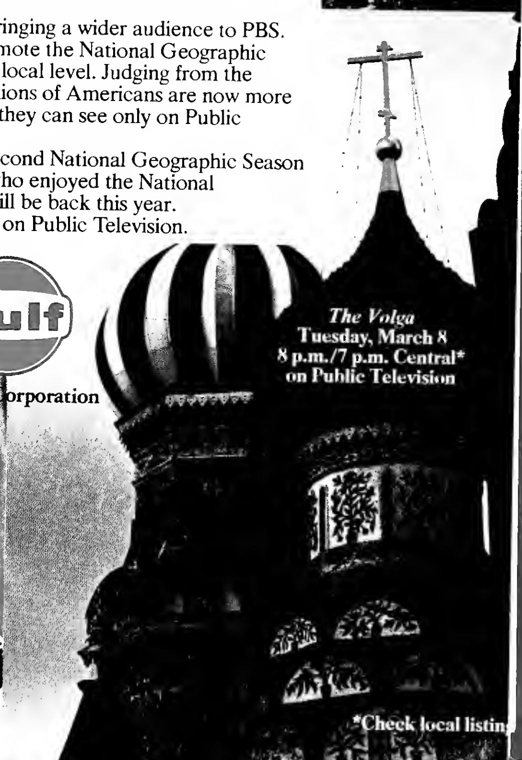


*Check local listin

mania for co-optation that had moved Europeans to "whiten up" the Lower Nile Valley and every other square centimeter of the historically better neighborhood.

About two decades before my birth, W.E.D. Stokes, a once well-known southern White horsebreeder and sometime contributor to the basically racist eugenics fad, concluded that the best future that bountiful nature held out for Blacks was that of a "satisfactory servant class." My grandfather and Mr. Stokes considered essentially the same evidence and arrived at equally erroneous conclusions. Natives and settlers have been doing that since the fluctuation of power occasioned the distinction between the two.

Native speculation about the deficiencies of settlers is ever rife. The question, "What is wrong with *this man*?" has engendered at least as much in the way of lively exchange among Blacks as that sophistic query, "What do *they* really want?" provides among settlers. Both questions are surface manifestations of deep currents of ethnocentrism. Among natives, settlers are presumed to behave the way they do because of the way they think. As settler behavior often displays a kind of rampant insensitivity and barbarism, it is a common native assumption that settlers are incapable of "correct" thinking.

The most wretched of natives is convinced by intercommunal daily life that natives are better people than settlers. This general feeling of moral supremacy is not just the workings of ethnocentrism, but a necessary consequence of the settler monopoly of power. Arrogance and rudeness, conscious and otherwise, flourish in equality's palmiest days, but become truly rampant as indispensable concomitants of the institutionalization of unfairness. Natives and settlers see everything, from the heavens to the hells, differently. The children of guilty wardens and the heirs of those who have survived the transgenerational concentration camp of slavery cannot possibly take the same view of their common history. When I was a child I thought the omnipresent divergence was immutable because the disparity between native and settler was a natural chasm.

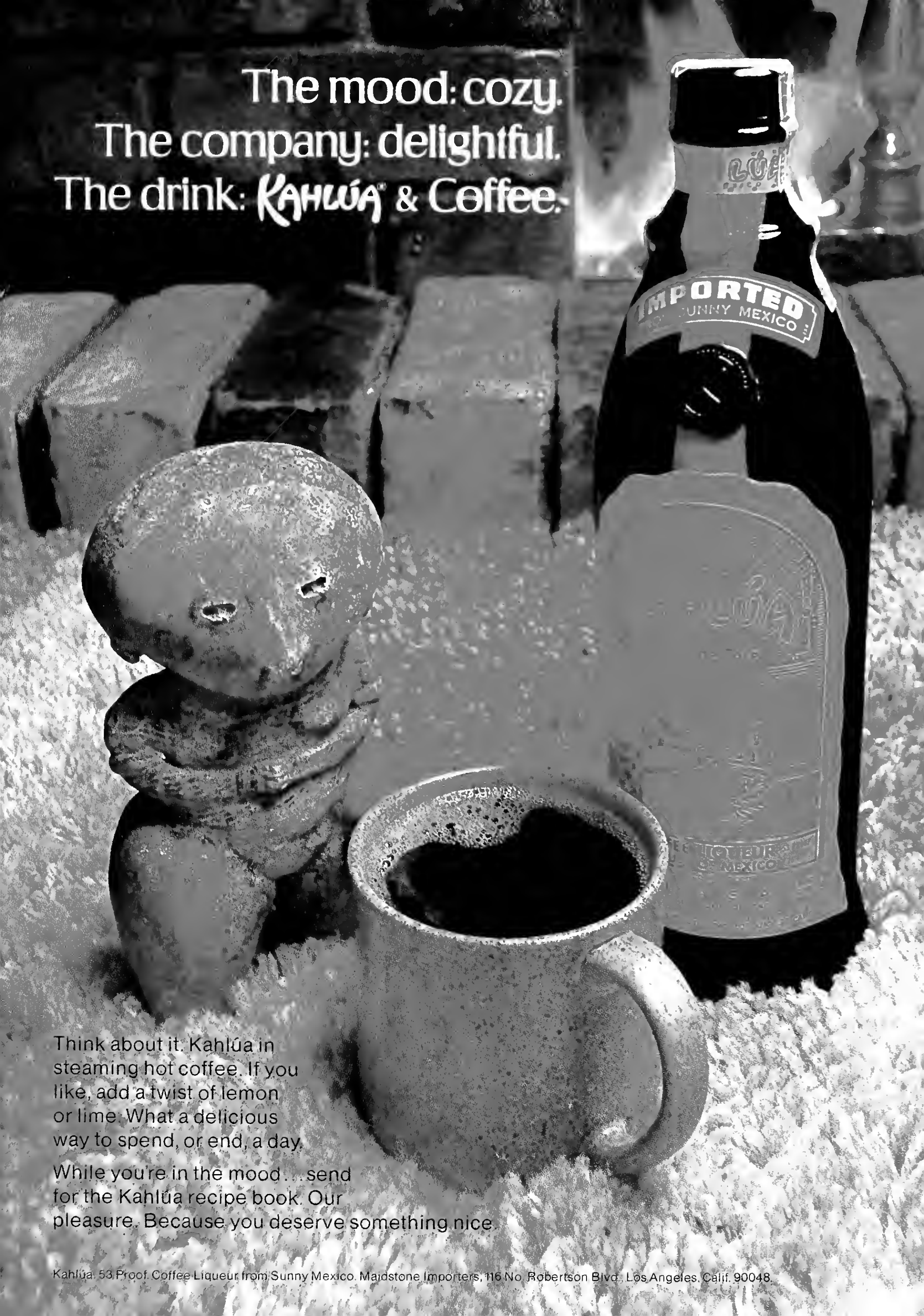
Even when education diverges least from indoctrination, it is dangerous stuff. It was on a Wednesday morning in the fifth year of my service in the elementary galleys that I experienced my first secular revelation. Dr. Margaret Mead was piped into our classroom, courtesy of CBS. On first looking into Mead's Oceania, I was impressed by distant places and the alliterative ring of Melanesian and Polynesian names, but the truly astounding thing about that presentation was the idea that the acquisition of knowledge of other people for humanistic, rather than strategic, considerations was an acceptable endeavor. My interest in geography expanded geometrically. Life hardly ever links currents with single, clearly definable sources, but that series of broadcasts, and more especially Dr. Mead's introduction to anthropology in them, acquainted me with a humanism above mere communalism. If there is an honorable medium that can assist natives and settlers to see each other as people worth listening to, and learning from, anthropology still seems the most likely candidate to me.

During the course of my training for a place in this discipline, and during the decade or so that I have been trying to teach people its salient premises, I have not met one anthropologist, native or settler, who has not manifested a desire to see anthropology as a medium of human tolerance and understanding. I have never met an anthropologist who would publicly subscribe to the notion that anthropology should content itself with being just another representative chip off the old hierarchical block. Indeed, there is a palpable recognition that social science has a high obligation to exceed the limits of a monodimensional social cult. Yet, every other native and many a settler I know in this profession senses a flaw in the discipline. In a word, it is parochialism. The settler view predominates. Often natives do not recognize their ethnicities as conventionally described in the largely settler-generated literature. One reputable native anthropologist, William S. Willis, Jr., has even suggested that "ethnographic monographs are simply novels and that theoretical concepts are but daydreams." A settler-skewed anthropology does not appear to be the most likely discipline to avoid the disorder and early sorrow that seem the reward of parochial cults, especially those with universalist pretensions.

Recently the Social Science Research Council held a conference that assembled a large sample of social scientists of widely varying, power-disadvantaged ethnicities. They were unanimous in the belief that they experience much greater difficulty in getting into print than do settler social scientists. Many of these scholars were of the opinion that certain of their concepts would never be accepted for publication, not because those ideas were silly or beyond sane consideration, but because they were anathema to conventional settler ways of thinking. The American Anthropological Association's Committee on Minorities and Anthropology conducted a study of the condition of minorities in anthropology and concluded in its 1973 report that

> The non-European anthropologist, thus, faces a double bind. He is invited to come into anthropology because he has a different perspective. When he expresses this view, he is punished by having his grade lowered or by being criticized. The student's spontaneous perceptions are, in this manner, discouraged or kicked out of him, and he is expected to fulfill the role of apprentice by incorporating the accepted perspective. These problems were referred to by some of our respondents as the "psychic pitfalls" in anthropology. Ways have to be developed wherein the student is encouraged to express, and the professional not discouraged from publishing, the minority perspective, even if it does not fit the usual manuscript category which comes across the editor's desk.

The most recent personal example of this kind of "psychic pitfall" is a three-page paternalistic jeremiad and tyro's catechism which came to me courtesy of the editor of a journal of medium obscurity. After a wholesome harangue on the responsibilities and canons of the professional life, there was a kindly assurance that my article was indeed possessed of the possibility of professional merit and a generous prediction that I might even make valuable contributions to social science. The solicited manuscript was deemed praiseworthy in every respect save one, but true to his settler patriarchal responsibility, this prince among editors did not shrink from his duty to inform me that any merit I might attain was very directly dependent upon a change in my logic, which was deemed to be utterly lacking.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There was more than a closing hint that if I could recast that deficient aspect (and I was generously offered assistance in these necessary repairs), all might be well. This cavalier catechist also took it upon himself to supply me with the names of other native social scientists to whom he had been moved to apply the righteous rod of his salubrious rejection.

I have yet to meet a native scholar who would advocate the automatic, uncritical acceptance of native speculation simply because it is native speculation. As the American Anthropological Association's own Committee on Minorities put it three years ago,

> It is not being suggested that nonminority professors accept uncritically the opinions of minority students and colleagues. But there is a difference between forcing a person to defend a position and dismissing a position as unworthy even of discussion.

The committee also emphasized that more than the shadow of that perilous gulf between the Third World and the North Atlantic Basin is cast in the anthropological distinction between natives as field producers of raw data and settler scholars as refiners of that crude data.

The minority ethnologist Francis Hsu has ascribed these negative tendencies to what he calls the "psychocultural bondage" of settlers—that is, a propensity to regard their own perspectives and logical models as some kind of absolute standard. Anthropologist Magoroh Maruyama's advocacy of the acceptance of alternate systems of logic, what he calls the "polyocular" view, springs from his belief that the serious consideration of non-Occidental, tribal, or peasant logical perspectives may reduce the margin of absolutist error not only in anthropology but in most areas of human existence as well.

Among the most perilous dividends of a monopoly of power is the ultimately pyrrhic opportunity to decree consensus. The most cursory reflection upon the massive difference a proper regard for my own communal opinions would have made in American foreign policy alone is enough to demonstrate the merits of genuine consensus. Having experienced tyrannical oppression at home and witnessed its baleful operation abroad, we are much more opposed to the general despotic condition than we are to any bloc manifestation of it. As a people, we are less inclined to accept Stephen Decatur's dictum about the automatic primacy of national self-interest. Our view of liberty and justice inclines toward the indivisible and hence militates against excessive pride in the national record or a demonic assessment of the deficiencies of others.

The profound sense of invisibility that is an integral part of every native's existence is rooted in the settler's ability to ignore our perspectives. One reason why so many natives, with the best will in the world, often cannot recognize their cultures in the standard literature is that settler social science, like settler life in general, has so bent our souls to its own conceit that they bear scant resemblance to reality as we perceive it. Settlers generally ignore what natives think of themselves and create the kind of native that answers their romantic requirements. Natives are not generally bemused by this prestigious pretense and often liken it to the game played by children in which they hide their faces and are convinced that because they can see no one, there must not be anyone to be seen. A choice and master major league baseball umpire, whose name escapes me, is said to have declared in reference to pitching, "It ain't nothin' till I calls it!"

We all know how the genuine principles of equanimity were suborned by a purely settler view of eligibility and justice in the largely segregationist history of the national sport. To natives it seems that settlers are prepared to amend the Berkeleyan absurdity to read: to be is to be perceived by settlers. Confidence in the existence of our own merit, in the People's Republic of China, and in a number of other realities, which settler perception either denies or perceives but dimly, inclines us toward different views not only of foreign policy but of most of the important questions of existence.

A couple of years ago, through the greatly appreciated subsidy of the National Endowment for the Humanities, the scope of this divergence was graphically reinforced in my mind. I conducted a number of folk field seminars in several Black communities. We considered the nature of our own cultures and evaluated some salient premises of ethnology. The same grave doubts of my grandfather's

generation are still firmly fixed in Black popular perceptions of settlers. There is a general awareness of the short shrift Black views are most often accorded. The firmly held opinion that settlers are incapable of a disinterested, let alone sympathetic, consideration of our points of view is as applicable to anthropology as it is to any other area of life.

A pervasive sense of the futility, indeed the peril, of intercommunal communications is general among the people whose candor and graciousness sustained my field research. Miz Rosa, who was among the first to hear of my fifth grade enlightenment, is still dispensing her incomparable buttermilk pie and timely admonitions. "Son," she counseled,

> you take a fool's advice and mind what you tell these whites. Now they ain't nothin' but meat men like the rest, but they do not like to hear what they don't want to hear. They will not thank you for not lying to them.

Seth, the short-order man, recovering in a diabetic ward from overexposure to his own noble cooking, offered much the same advice.

> Look, man, this is a good gig you got, so if you know what I know, you will tell this man what he want to hear. He ain' gon' believe nothin' else and he will hang you up if you try to tell him anything he don' want to dig.

Gabriel, the root doctor and machinist, offered this variation, which reverberated slightly in his newly acquired empty chapel.

> Chahlie just ain' no niddygriddy man. He cannot get with natural numbers. He's bad enough to make anything into a big number. Now he has been doing that for so long that he don' know how to tell how good or how big anything really is. I mean he ran this game on hisself trying to do a number on us. Now if you had done such a number, would you want to hear about it? Well, he don't either.

The relative powerlessness of Black people to influence the foreign and domestic course of their lives finds expression in observations that touch upon a wide range of subjects. Graciela, the only one of her Dominicano father's "outside children" too Black to be integrated into his legitimate Latino family, is already far too wise in ways that should never concern a nine year old.

> You know something? Miz Lula says it will rain down fire that will kill the wicked. Every night I pray that the fire will come. I don't care if it gets me too as long as it gets them.

Flood broils pork ribs and flatfish, which he serves with sweet white bean sauce to the nonfastidious few. His grill is an abandoned bedspring, and his most frequent domicile is a vacant lot where those who are lost in cheap wine conduct the interminable sessions of the SALS, the Standing and Leaning Society. We exchanged pleasantries and gifts. Two ducks for a long pan full of exquisitely grilled butterfish. At my invitation, a number of people assist in the leisurely assault upon the butterfish and a seminar is launched. Flood, the founder of what grew to be a genuine symposium, offers the following comment.

> First you got to remember that it is not in the color. Now Holt is as White as anybody need to be, and if I wrap a towel 'round my knob, I'm home free. It is power. Last night there was much moon, I mean uku moon! Now we say, what kind of thing could call hisself a man and pis on the revern' moon? But anybody that don't have somebody to call his hand might do some trick like that. Right now the whitefolks got the sayso and they doing what most people do when they got the sayso. Now that's why they gon' blow it, everybody knows that. I'm out here in this damn lot now because nobody couldn't tell me a damn thing. I know that's why most of us are doing what we are doing. My brother comes down here and tries to talk sense to me but I don't pay him no mind because I don't have to! Now it's the same way with the man.

Though surely not attributable to any genetic incapacity, the manifest deficiencies of monodimensional consensus by decree occasion grievous loss for settler and native alike. Anthropology could be a vital part of that interethnic entente that is an indispensable condition of the human future. The relevance of anthropology in a postimperialist society will probably be established by the current exertions of anthropologists to make our discipline a precursor of a better way of life.

I do not mean to imply that the integration of perspectives in theory building is necessarily going to lead to an unprecedented burgeoning of instant enlightenment. Over the long course it seems a reasonable expectation that a number of views are at least as likely to carry us in the general direction of truth as a single perspective. Quite apart from the probability of enrichment, we might do more to foster a climate of honorable integration in theory and staff because our best instincts tell us that this is what the sanest human future demands of us. It will require a democratic, humanist act of will for natives and settlers to really listen with respect to each other, even in the limited context of anthropology.

I know a number of anthropologists from native and settler cultures who have mastered this astounding accomplishment. As any native or settler who has managed it can affirm, a number of heritages is an improvement on any one. It is equally certain that the individual or nation arbitrarily confined to the strictures of a single way of being human is incalculably poorer for that isolation. Is it not a matter of cosmic tragedy that we will never hear Robeson, Hayes, Maynor, and Anderson as principals in a well-recorded Bach and Handel oratorio series? Would we not all have been cosmically deprived if the vagaries of war or prejudice had confined the glory of Hugues Cuenod, Elizabeth Schwarzkopf, or Aksel Schiøtz to their natal corners? How many natives, secure in their garrison solidarity, will shield themselves against beauty because it proceeds from the same direction as so much misery? How many settlers will live and die without perceiving the same loss? Imagine! Never to have heard Jim Bartow sing Dunbar or Dowland songs!

If there is hope for the civil survival of our species, in all its glorious diversity, it resides in the certainty that my grandfather's "gene for civilization" was one of those social mirages made more apparent than real by the pain he bore and the position he held on the nether millstone of caste.

John L. Gwaltney is associate professor in the Department of Anthropology at Syracuse University.

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Managing the Earth's Surface

The environment must be thought of as a closed system

Georges Bank is a large shoal area off the Massachusetts coast. It is one of the world's richest fishing grounds and a spawning and nurture area for many of the fish that are caught in the northwestern Atlantic. Georges Bank is also one of the two or three most promising sites for oil exploration on the eastern seaboard. Almost no one believes that oil wells in the area will enhance the fisheries; some believe the development will be disastrous.

The controversy over the prospect of oil wells on fishing grounds embodies one of the classic conflicts of our time—the confrontation between the demands of an oil-hungry industrial system and the need to preserve a basic living resource. We have not yet found a general solution for this kind of conflict, which daily grows more serious.

Spokesmen for oil development represent a wealthy and politically powerful industry. American fishermen are largely individual entrepreneurs whose catch comes from a poorly managed natural ecosystem that is being rapidly degraded by overharvesting and such other factors, quite apart from oil, as pollution and the destruction of marshes. According to the values set by our economic system, the fisheries are less important at present than the oil.

The situation seems paradoxical. Fish are potentially an infinitely renewable source of protein and are obviously needed in a world in which starvation is becoming increasingly common. How can the value of industrialization so far exceed the value of food?

The reasons are complicated. They include the argument that the oil will be used to increase agricultural yields in excess of any losses in fisheries. But quite apart from this doubtful thesis is the simple fact that those who are hungry are hungry because they are poor. They are not participants in the international commerce in food. Their needs are not a factor in the controversy except as governments choose to make them so. The rich, those who have energy and can use it to expand their control over other resources, are not yet short of food. And the economic systems of the industrialized countries have put the prices of energy and food into a balance geared solely to the demands of world markets. In that marketplace, food appears to be cheap for those in industrialized nations, but it is well beyond reach for the world's poor, who consequently go hungry.

Two perspectives dominate discussions of this controversy. If we take a world view and are moved by normal compassion for our fellow beings, we would conclude that the fishery is more needed than the oil. If our view is a coldly objective national one, we might choose the oil as necessary for the maintenance of our international posture in politics and commerce. Because the United States has enough food at the moment, we can afford to lose the fishery, even if the cost should be that high. But the issue is still further polarized. Certain technologists, politicians, and economists believe in salvation through technological growth that, it is claimed, will feed economic growth indefinitely. Energy is the key resource in that philosophy; with cheap energy, proponents are convinced, we can produce whatever other resources we require, potentially even food. On this basis, a no-holds-barred approach to energy development in support of industry is justified.

Others argue with equal force that technology has produced no new basic resource; it has simply made possible the transformation and transportation of other resources, such as food, around the world—in forms and to places convenient for humans. These partisans would not abandon technology, far from it, but they do assert that the benefits of industrial growth are finite and cannot be equally shared by all of the earth's current four billion people, let alone the billions more to come. Their argument also contends that the benefits of growth are now outweighed by environmental costs that are not yet properly tallied. Further, the arithmetic of exponential growth of all kinds—in population and in demand for food, energy, and other resources—coupled with the recognition that oil reserves and agricultural production have their limits, assures that our lives will change in the approaching years at an accelerating rate. Exponential growth also assures that collisions between short-term profit and long-term maintenance of biotic, or organic, resources are bound to become steadily more serious. Unfortunately, there is no evidence that our present means of managing these resources can cope with the challenge.

The pattern of environmental protection practiced at the moment in the United States, and frequently elsewhere, is largely based on the clearly false assumption that resources are large in proportion to the pressures placed on them and that this relationship will hold indefinitely. A corollary has been the concept of an "assimilative capacity," the assumption that the environment can absorb a certain amount of waste and other man-made pollution without ill effects.

An assimilative capacity can presumably be divided among different polluters and redivided as potential polluters increase in numbers. The putative capacity is vague and elusive, however. A stream may have the capacity for oxidizing organic matter at a certain rate and be assigned an assimilative capacity. But that does not necessarily mean that other substances, introduced with the organic matter, will be rendered innocuous at the same rate, if at all. The concept of assimilative capacity encourages a pattern of air and water use that virtually assures progressive degradation by encouraging the idea that some degree of pollution is acceptable. The sources of pollutants may be large and the political and economic pressures to allow pollution to continue may be almost irresistible.

A government's burden of regulation could become virtually impossible.

The alternative is clear—in a world condemned to soaring population and even more rapidly soaring demands on resources, the environment must be treated as a small, closed system. In practice, this means that countries would not befoul the air or water held in common; cities would recirculate their water, nutrients, metals, and other resources; industries would accept the same responsibility for their waste products that they now do for their salable products; agriculture would not poison the air or waterways with pesticides or fertilizers; and power companies would not usurp public bodies of water in the production of energy. This approach to the management of the surface of the earth, Utopian as it may seem, is part of the cost of preserving living resources under intensified use. The basic principle is not pollution within limits, but preservation of the physical, chemical, and biotic integrity of the earth. A version of that objective has already been applied to the management of national water resources and appears as the policy statement in the Water Pollution Control Act Amendments of 1972.

No one expects a transition to closed systems to occur immediately. Indeed, the transition will probably not even begin until its feasibility has been demonstrated through research, which in turn will obviously be complex and require several years. It will doubtless include much of the work already under way in support of current patterns of regulation, but it will also require entirely new explorations of the question of how to achieve growth within limits.

Meanwhile, three topics seem to be of overwhelming importance in aiding this new effort. The first involves carbon, the basic element that supports human life. It is fixed in photosynthesis and thereby made available in various forms for human use. There is abundant evidence that the world carbon budget is being grossly affected by human activities. The

major manifestation is the accumulation of carbon dioxide in the atmosphere. The concentration is now increasing at the rate of 0.8 to 1.5 parts per million per year and the rate itself seems to be going up.

The cause of the increase is generally believed to be the combustion of fossil fuels, but the destruction of forests and the oxidation of humus are probably also contributory causes. Despite the fact that two-thirds of the surface of the earth is water, two-thirds of the total photosynthesis on earth occurs on land; most of it is attributable to forests. There is good reason to believe that the total amount of photosynthesis on earth is diminishing, although there is at present no detailed analysis of the question. To the extent that photosynthesis is a measure of the healthy functioning of the biosphere, a worldwide decline in the process would be a serious matter. There is, moreover, the possibility that increasing amounts of CO_2 in the atmosphere could lead to climatic changes that would alter agricultural productivity over large areas. There is, accordingly, a need for increased understanding of the human influence on the world carbon budget with special emphasis on the interactions of living systems with atmospheric CO_2. This should probably be a major international scientific effort that might ultimately recommend control of the emission rate of CO_2.

The second topic, an appraisal of changes occurring in the populations of the earth's flora and fauna, emerges from a detailed consideration of the first. Chronic or long-lasting changes in the physical or chemical environment can cause predictable changes in the structure of natural communities. Those populations favored by adverse environmental changes are hardy, small-bodied organisms that have high reproductive rates—populations that include our so-called pests. Regions dominated by these populations are extremely difficult ones in which to maintain human life. The stages, extent, and causes of this pattern of biotic impoverishment, currently largely ignored, are thus appropriate matters for investigation.

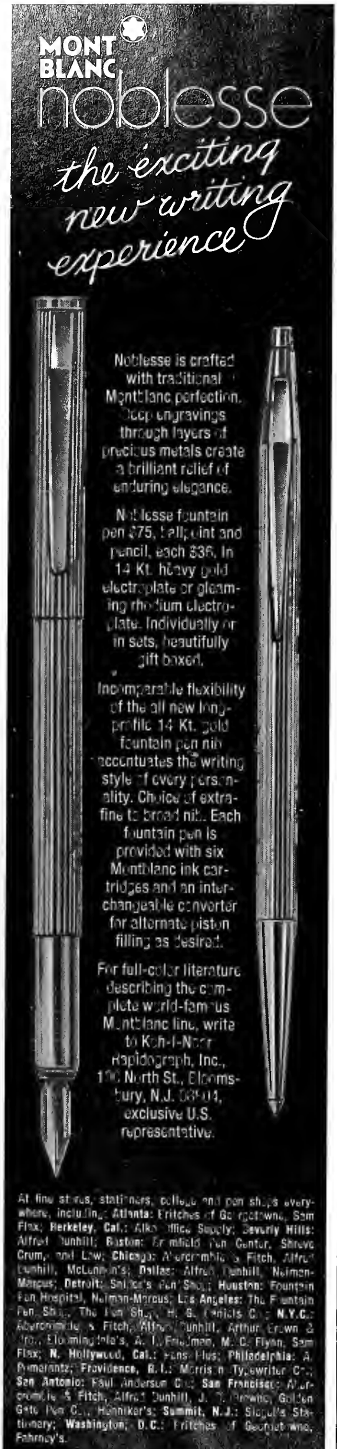
The third topic is in some ways the most important because it is the first step in adjusting modern cities to the recognition of a finite earth: the recovery of the water and nutrients in sewage. The pattern of sewage disposal developed over the past century

in the Western world is totally inconsistent with an ever more intensive use of natural resources. The current tendency in urban areas, for instance, to install large sewage collection systems that release treated sewage into the coastal oceans is counterproductive. It aggravates shortages of fresh water and of the chemical components of fertilizers and increases the pollution of the coastal seas. To the extent that industrial wastes are incorporated into sewage, serious toxic hazards to humans may be associated with this treatment.

Recent research has raised hopes that living systems—combinations of ponds, marshes, and plant communities—can be used to purify the water in sewage and recover the nitrogen, phosphorus, potassium, and other elements normally lost. The utilization of living systems under controlled conditions would offer the possibility of a number of relatively small and inexpensive treatment facilities to serve small municipalities or segments of larger ones and restore the water for local reuse.

The issues involved in the management of the environment seem extraordinarily complicated. But they are complicated only if we wish them to be so. The central principles of the science of environment are no more complicated than the central principles of any other science or of language or arithmetic. What is important is that we see with some clarity what is happening to the environment and proceed to solve the problem of its degradation. To the extent that we continue to accentuate the trends of the past decade, we ourselves become causes of degradation rather than cures. There is a powerful argument at present that much of the technical and scientific effort of the country, including that at some of its major laboratories, is more detrimental to the environment than constructive. The real lesson from the controversy over mixing oil and water on Georges Bank is that to date we have neither a solution for the management of the environment nor the research that could lead to a solution. Changing this situation will require powerful political leaders. And the time to make that change is long overdue.

George M. Woodwell is director of the Ecosystems Center at the Marine Biological Laboratory, Woods Hole, Massachusetts.



Letters

Primates in Peril?

In "Perils of Primates" (October 1976), Jaclyn Wolfheim states that zoological gardens are major recipients of primates. Nothing could be less true. Of the thousands of primates that enter the United States each year, only a minor percentage (perhaps as little as 0.1 percent) are acquired by zoos. Furthermore, no gorilla or orangutan acquired from the wild has legally entered the United States since 1970. As for lion-tailed macaques being imported, nothing could be further from the truth. Most lion-tailed macaques now kept by zoos are captive born from wild-caught parents imported in the 1950s.

The statement that survival and birth rates of zoo-kept primates are "suspected to be low" is nonsense. Most primates breed well in captivity and surplus primates are now commonly available. Primates thrive and live long in most captive situations (all physical needs are met and hopefully social needs are also met).

Today zoos are breeding their own stock, with excess animals being provided to other zoos.

ALLEN C. PARKER
Silverdale, Washington

THE AUTHOR REPLIES:

Zoos do import fewer primates than biomedical users, but zoos prefer exotic and rare species that are least able to withstand further depletion. These vulnerable species, including all of the great apes, do not breed well in captivity. Successful captive breeding through several generations has been achieved only with the common, hardy macaques and baboons. If zoos actually produce a surplus, then the annual importation of more than 20,000 primates for nonresearch purposes should be unnecessary.

JACLYN WOLFHEIM

Tragedy in Timor

Shepard Forman, the author of your interesting article "Spirits of the Makassae" (November 1976), shares my deep concern about a problem now threatening all the people of East Timor. Their emergence from four centuries of Portuguese colonial rule has met a new obstacle: invasion by thousands of Indonesian troops. According to a *New York Times* report of February 15, 1976, more than 60,000 people have died in these attacks by Indonesia, a nation of 130,000,000, against a people numbering only 650,000.

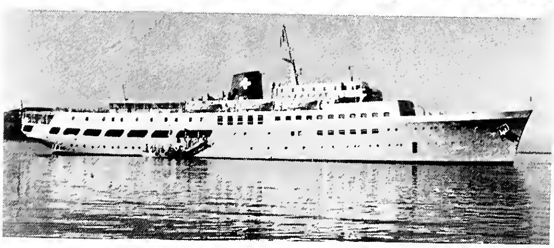
The United Nations has twice called for the complete and immediate withdrawal of all Indonesian forces from East Timor and a democratic process to determine whether the people of that country truly want "integration" as Indonesia's twenty-seventh province (U.N. Decolonization Committee Document No. 76-36163). Of particular concern to all Americans is surely the $46 million in military aid given this past year to the military government in Indonesia. For further information may I draw your readers' attention to a documented publication by concerned Americans, *East Timor: The Hidden War*, which can be obtained for $1.25 from East Timor Defense Committee, 166 Fifth Avenue, New York, New York 10010.

DR. RICHARD W. FRANKE
Harvard University School of Public Health
Boston, Massachusetts

A Predator Proposal

In reference to your article in the June/July issue regarding the goats of Santa Catalina Island, mention was made about the difficulties encountered in eradicating goats from island situations of this kind. I am always curious why no one considers introducing natural predators in such situations. (At considerably less cost than hunting programs, which have apparently proven to be of little value.)

I suppose the usual response to such a suggestion would be that it would throw the natural ecology out of balance. In this particular case, my



response to that would be, "What natural ecology?" If man must create an imbalance in the first place, surely a natural check is the most obvious answer.

I am a little sympathetic to the goats anyway. They were the first European settlers in a way, and if they could be controlled naturally perhaps they could remain. Much smaller numbers would cause much less damage. They don't require the whole island . . . surely, some small place is suitable for them.

BUD LAWHEAD
Los Angeles, California

Freezing Raspberries

Raymond Sokolov's "Best of the Brambles" (June/July 1976) was timely and nostalgic. However, I disagree with his statement that raspberries do not freeze well: "The whole fruit doesn't freeze well; frozen raspberries are the next thing to raspberry syrup."

We have one hundred and fifty feet of the luscious Canby variety raspberries and they yield to ourselves and friends at least thirty pounds each year. I immediately freeze the *whole* berry after picking, in any handy plastic carton, without any sugar. When these beautiful berries are defrosted over several hours—if left in the refrigerator overnight—the berries are firm and as delicious as fresh ones. The secret probably is freezing them without delay and omitting the sugar until ready to eat.

EUNICE C. BURNETT
Portland, Oregon

Diagrams

In your August/September issue, in the interesting article "The Interpretation of Diagrams," Stephen Jay Gould refers to "so-called Mae West" diagrams and then adds, "pardon the sexism of a profession still overwhelmingly male . . . and none of us invented the term anyway." If Mr. Gould realizes the offensiveness of such a term, he should stop using it, and encourage his colleagues to do the same.

SHERYL ROSE
Los Angeles, California

A Bouquet

A word of appreciation for Stephen Gould's essays. I hope you'll continue his contributions indefinitely.

RONALD S. FISHMAN, M.D.
Potomac, Maryland

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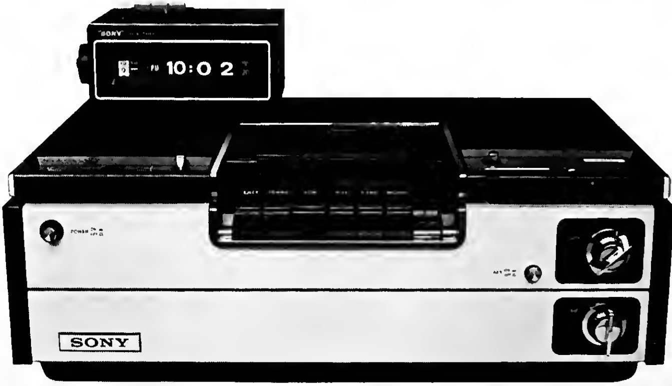

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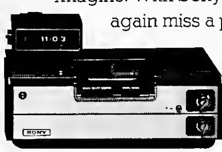

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by Stephen Jay Gould

The Advantages of Eating Mom

Some insects have evolved an effective life strategy: forget father and consume mother from inside

Since man created God in his own image, the doctrine of special creation has never failed to explain those adaptations that we understand intuitively. How can we doubt that animals are exquisitely designed for their appointed roles when we watch a lioness hunt, a horse run, or a hippo wallow? The theory of natural selection would never have replaced the doctrine of divine creation if evident, admirable design pervaded all organisms. Charles Darwin understood this, and he focused on features that would be out of place in a world constructed by perfect wisdom. Why, for example, should a sensible designer create only on Australia a suite of marsupials to fill the same roles that placental mammals occupy on all other continents? Darwin even wrote an entire book on orchids to argue that the structures evolved to insure fertilization by insects are jerry-built of available parts used by ancestors for other purposes. Orchids are Rube Goldberg machines; a perfect engineer would certainly have come up with something better.

This principle remains true today. The best illustrations of adaptation by evolution are the ones that strike our intuition as peculiar or bizarre. Science is not "organized common sense"; at its most exciting, it reformulates our view of the world by imposing powerful theories against the ancient, anthropocentric prejudices that we call intuition.

Therefore, I was not surprised that my passing comments on the life history of cecidomyian gall midges (May 1976) inspired several readers to ask for more details. For these tiny flies conduct their lives in a way that tends to evoke feelings of pain or disgust when we empathize with them by applying the inappropriate standards of our own social codes.

Cecidomyian gall midges can grow and develop along one of two pathways. In some situations, they hatch from eggs, go through a normal sequence of larval and pupal molts, and emerge as ordinary, sexually reproducing flies. But in other circumstances, females reproduce by parthenogenesis, bringing forth their young without any fertilization by males. Parthenogenesis is common enough among animals, but the cecidomyians give it an interesting twist. First of all, the parthenogenetic females stop at an early stage of development. They never become normal, adult flies, but reproduce while they are still larvae or pupae. Secondly, these females do not lay eggs. The offspring develop live within their mother's body—not supplied with nutrient and packaged away in a protected uterus but right within the mother's tissues, eventually filling her entire body. In order to grow, the offspring devour their mother from the inside. A few days later, they emerge, leaving a chitinous shell as the only remains of their only parent. And within two days, their own developing children are beginning, literally, to eat them up.

Micromalthus debilis, an unrelated beetle, has evolved an almost identical system with a macabre variation. Some parthenogenetic females give birth to a single male offspring. This larva attaches to his mother's cuticle for about four or five days, then inserts his head into her genital aperture and devours her. Greater love hath no woman.

Why has such a peculiar mode of reproduction evolved? It is unusual even among insects, and not only by the irrelevant standards of our own perceptions. What is the adaptive sig-

nificance of a mode of life that so strongly violates our intuitions about good design?

To answer these questions, we proceed by the usual mode of argument in evolutionary studies: the comparative method. (Louis Agassiz did not act capriciously when he gave to the building in which I work the name that has puzzled so many generations of visitors to Harvard—the Museum of Comparative Zoology.) We must find an object for comparison that is genetically similar, but adapted to a different mode of life. Fortunately, the complex life cycle of cecidomyians provides us with a key. We do not have to compare the asexual, larval mother with a related species of uncertain affinity and genetic resemblance; we may contrast it with the genetically identical, alternate form of the same species—the normal, sexual fly. What then is different about the ecology of parthenogenetic and normal forms?

The cecidomyians feed and dwell on fungi, usually mushrooms. The mobile, normal fly fills the role of discoverer: it finds the new mushroom. Its offspring, now living on a superabundant food resource, reproduce asexually as larvae or pupae and become the flightless, mushroom-eating form of the species (a mushroom can support hundreds of these tiny flies). We know that parthenogenetic reproduction will continue as long as food is abundant. One investigator produced 250 consecutive larval generations by supplying enough food and preventing crowding. In nature, however, the mushroom is eventually used up.

German biologist H. Ulrich and his coworkers have studied the sequence of changes in response to decreasing food in the species *Mycophila speyeri*. When they have abundant food, parthenogenetic mothers generate all female broods in four to five days. As the supply of food diminishes, all male and mixed male and female broods develop. If female larvae are not fed at all, they grow into normal flies.

These correlations have a fairly unambiguous adaptive basis. The flightless, parthenogenetic female stays on the mushroom and feeds. When it exhausts its resources, it produces winged descendants that find new mushrooms. But this only scratches the surface of our dilemma, for it does not address our central question: Why reproduce so quickly as a larva or

pupa (many insects have flightless, adult forms) and why self-destruct by a supreme sacrifice to one's children?

I believe that the solution to this dilemma lies in the phrase "so quickly." Traditional evolutionary theory concentrated on morphology in framing adaptive explanations. What, in this case, is the advantage to mushroom feeders of a persistent juvenile morphology in reproducing females? Traditional theory never found an answer because it was posing the wrong question. During the last fifteen years, the rise of theoretical population ecology has transformed the study of adaptation. Evolutionists have learned that organisms adapt not only by altering their size and shape but also by adjusting the timing of their lives and the energy invested in different activities (feeding, growth, and reproduction, for example). These adjustments are called "life history strategies."

Organisms evolve different life history strategies to fit different types of environments. Among theories that correlate strategy with environment, the theory of *r*- and *K*- selection, developed by R. H. MacArthur and E. O. Wilson in the mid-1960s, has surely been the most successful.

Evolution, as usually depicted in textbooks and reported in the popular press, is a process of inexorable improvement in form: animals are delicately "fine tuned" to their environment through constant selection of better-adapted shapes. But several kinds of environments do not call forth such an evolutionary response. Suppose that a species lives in an environment that imposes irregular, catastrophic mortality upon it (ponds that dry up, for example, or shallow seas ripped up by severe storms). Or suppose that food sources are ephemeral and hard to find, but superabundant once located. Organisms cannot fine tune themselves to such environments for there is nothing sufficiently stable to adjust to. Better in such a situation to invest as much energy as possible into reproduction—make as many offspring as you can, as quickly as you can, so that some will survive the catastrophe. Reproduce like hell while you have the ephemeral resource, for it will not last long and some of your progeny must survive to find the next one.

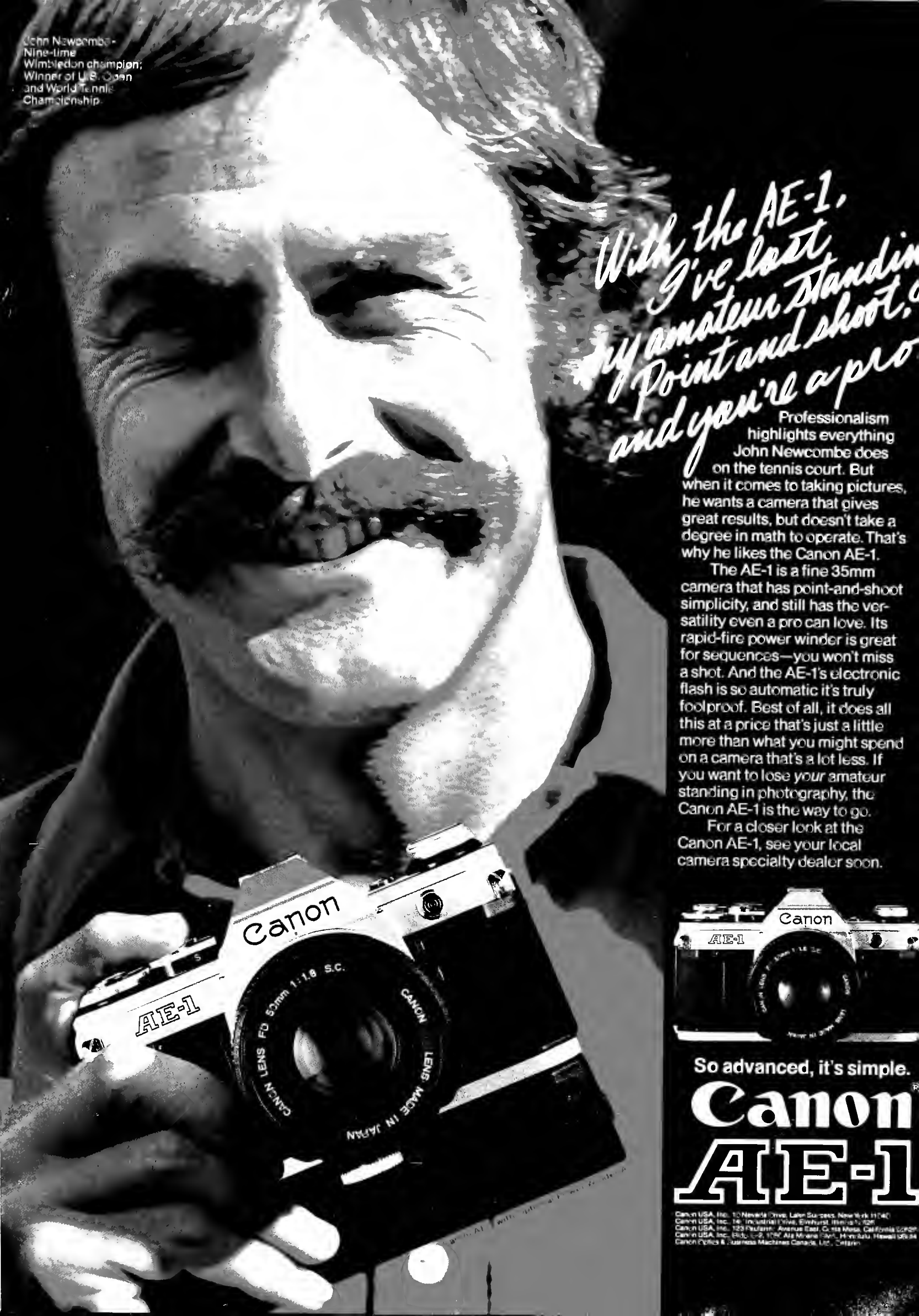
We refer to evolutionary pressures for the maximization of reproductive effort at the expense of delicate morphological adjustment as *r*-selection; organisms so adapted are *r*-strategists (*r* is the traditional measure of "intrinsic rate of increase in population size" in a set of basic, ecological equations). Species that live in stable environments, near the maximum population size that the environment can support, will gain nothing by producing hordes of poorly adjusted progeny. Better to raise a few, finely tuned offspring. Such species are *K*-strategists (*K* is the measure of environmental "carrying capacity" in the same set of equations).

The parthenogenetic larval gall midges live in a classical *r*-environment. Mushrooms are few and far between, but superabundant when found by such a tiny fly. Cecidomyian gall midges therefore gain a selective advantage if they use newly discovered mushrooms for building up their population as rapidly as possible. What, then, is the most efficient way to build a population quickly? Should the midges simply lay more eggs or should they reproduce as early as possible during their lives? This general issue has inspired a large literature among mathematically inclined ecologists. In most situations, the key to rapid increase is *early* reproduction. A 10 percent decrease in age at first reproduction can yield the same effect as a 100 percent increase in fecundity.

Finally, we can understand the peculiar reproductive biology of cecidomyian gall midges: they have simply evolved some remarkable adaptations for early reproduction and extremely short generation times. In so doing, they have become consummate *r*-strategists in their classical *r*-environment of ephemeral, superabundant resources. Thus, they reproduce while still larvae, and almost immediately after hatching, they begin to grow the next generation within themselves. In *Mycophila speyeri*, for example, the parthenogenetic *r*-strategist undergoes only one molt, reproduces as a true larva, and manufactures up to 38 offspring in five days. The normal, sexual adults require two weeks to develop. The larval reproducers maintain a phenomenal capacity for increase in population size. Within five weeks after its introduction into a commercial mushroom bed, *Mycophila speyeri* can reach a density of 20,000 reproductive larvae per square foot.

We may again pursue the comparative method to convince ourselves that this explanation makes sense. The cecidomyian pattern has been followed by other insects that inhabit a similar set of environments. Aphids, for example, feed on the sap of leaves. A leaf, to these tiny insects, is much like a mushroom to a gall midge—a large, ephemeral resource to be converted quickly into as many

Gall Midges, family Cecidomyiidae David Overcash; Bruce Coleman, Inc.



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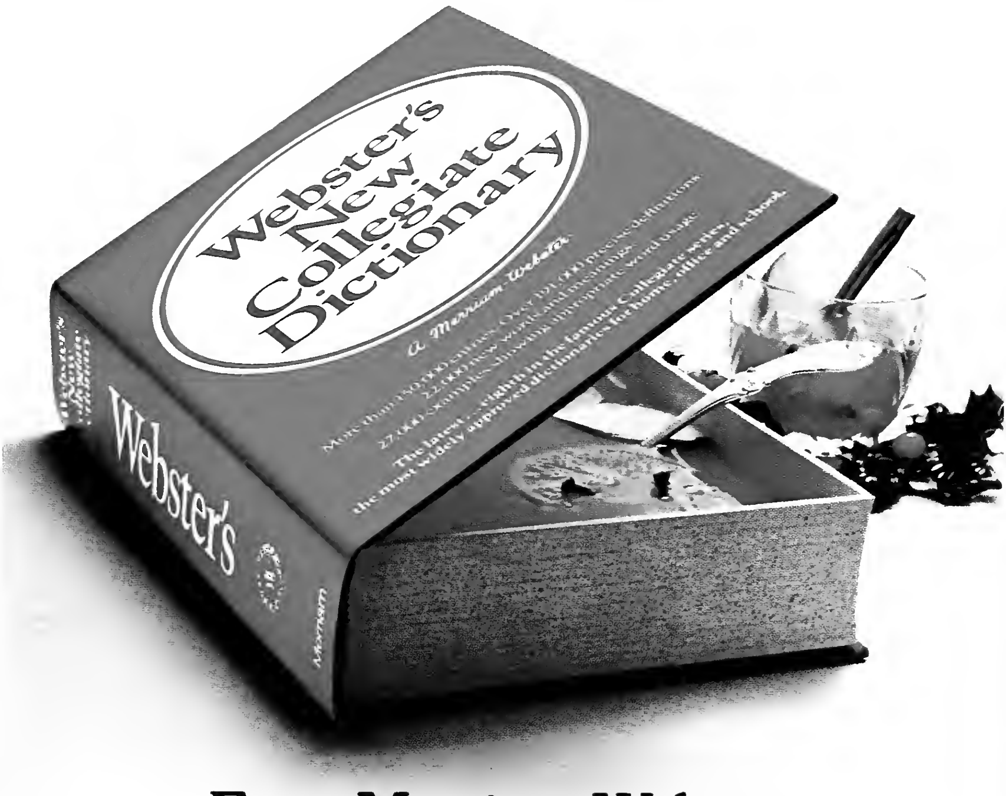
aphids as possible. Most aphids have alternate parthenogenetic forms—wingless and winged (they also have an overwintering, sexual form, which need not concern us here). As you have probably already guessed, the wingless form is a flightless feeder. Although it is not a larva, it retains many features of juvenile morphology. It also maintains a remarkable capacity for early reproduction. Embryonic development actually begins in a mother's body before her own birth, and two subsequent generations may be telescoped within each "grandmother." (Aphids, however, are not consumed by their offspring.) Their capacity for rapid increase in population size is legendary. If all its offspring lived to reproduce, a single female of *Aphis fabae* could produce 524 billion progeny in a year. Winged aphids develop more slowly when the leaf is used up. They fly off to a new leaf, where their offspring revert to the wingless form and begin their rapid cycling of generations.

What at first seemed so peculiar now seems eminently reasonable. It may even be an optimal strategy for certain environments. This much we cannot claim, for so many aspects of cecidomyian biology are entirely unknown. But we can point to the uncanny convergence upon the same strategy by a completely unrelated organism, the beetle *Micromalthus debilis*. This beetle lives and feeds in wet, rotting wood. When the wood dries out, the beetle develops a sexual form to search for new resources. The wood-dwelling, feeding form has evolved a set of adaptations that repeats the features of cecidomyians down to the most complex and peculiar detail. It also is parthenogenetic. It also reproduces at a morphologically juvenile stage. The young also develop within the mother's body and eventually devour her. Mothers also produce three types of broods: females only when food is abundant and males only or males and females when resources diminish.

We humans with our slow development (see my column of May 1975), extended gestation, and minimal litter size are consummate *K*-strategists and we may look askance at the strategies of other organisms, but in their *r*-selective world the cecidomyians are surely doing something right.

Stephen Jay Gould teaches biology, geology, and the history of science at Harvard University.

was·sail



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An Even, Gentle Heat

The oven, in various forms, has been with us since prehistoric times

The first time I lit an oven, in a gas range with no pilot light, it responded with a small explosion that singed my eyebrows. Ever since, I have approached all ovens with respect, even flame-free electric models. This is irrational, no doubt, and probably derives from the same primeval fear of hot, enclosed spaces symbolically expressed in the Hänsel and Gretel tale or by Lear's "sulphurous pit."

I leave it to your own post-Freudian imaginations to speculate on the meaning of this widespread phobia and hasten to add that, whatever its cause, oven-fear is based on a fundamental misunderstanding. The purpose, the essential virtue of ovens is that they keep fire at bay: they disperse its danger, spread out its power, and tame it. What, after all, is an oven, but a large pot with heavy walls?

We don't, in fact, know how or why the first oven was invented. The oven is prehistoric. Many early cultures had them: Egyptian, Sumerian, and Greek, to name only well-known examples. But even if we cannot locate the exact route that led to the first oven, it is fairly obvious from proto-ovens, and other simple methods of slow, enclosed cookery surviving in contemporary use, that ovens evolved in one of two ways. The pot is one model; the pit is another.

Once you know how to make fireproof pots, you can heat them over a fire and then use the retained heat to cook with. This method is shown on a tomb built about 2500 B.C. in Saqqara, Egypt. It is a short step from these oven-pots to the larger, beehive ovens made from clay and brick that were the normal form of oven in the Near East until quite recently.

The alternate route to the oven is even simpler. It uses heat-retentive stones and/or embers and a hole in the ground. The New England clambake began this way. The Indians dug a pit and further insulated it with wet seaweed, which protected the clams, steamed them, and gave them a special flavor. A quite similar method was reported in 1959 by Rev. Wilhelm Rechnitz from Murray Island in the Torres Strait between Australia and New Guinea. The islanders build a wood fire and cover it thickly with stones the size of a fist. When the fire burns down, they use long wooden poles to spread the stones over a circular area. Over the stones go parcels made up of sliced yams, sweet potatoes, pumpkin, and shellfish or meat mixed with coconut milk and wrapped in banana leaves. Then comes a layer of palm branches and slightly dried banana leaves, then sackcloth, and finally plenty of sand, which completely covers the earth oven, or *kap mauri.* After two or three hours, at least, the oven is opened up and the parcels are served on plates. Mixed vegetables prepared in this way are called *sopsop,* according to Rechnitz, who adds that "Europeans who visit the Islands always enjoy it."

The Maori also developed a steaming pit of a similar type, which they call by various names, among them *hangi* and *umu.* And we may imagine that sophisticated Western visitors enjoy food baked in them as well as they do *sopsop.* The Maori also have a method of cooking called *turchu,* in which they bury birds in wet earth, then build a fire over them. Alternatively, the Maori put food in a vessel, place it in the pit, and bury it.

All these methods of what might be called burial cookery hark back to what must have been the original mode of oven cuisine: food roasted in the embers of a campfire. We do this today with potatoes in their jackets and unshucked corn, foods that come to us encased in their own natural "ovens." It is virtually certain,

moreover, that the oven concept was discovered accidentally when some foodstuff fell into a slow fire and was discovered, probably the next morning, deliciously cooked and still warm.

The ur-Escoffier who first hit on burial cookery would probably smile to see the most innovative chef in modern France proclaiming this method as a paradigm of up-to-date culinary sophistication. Paul Bocuse likes to bake the truffled cervelas sausage of Lyons in aluminum foil. He first pours in a half liter of Beaujolais, then twists the foil tightly shut, wraps it in wet newspaper, and buries the entire contraption under wood embers for forty-five minutes. Bocuse also recommends roasting chicken interred in seven pounds of sea salt inside a cast-iron pot. And like many French (and Thai) chefs, he cooks fish in a paper or foil envelope, *en papillote,* for a delicate effect.

These last two dodges are particularly refined, for they take place inside a modern oven, which itself has been carefully designed to produce an ideally even and gentle heat that radiates toward the food from all sides. Something close to this sort of thermal sophistication has been around for a long time, of course, but without the exactness of temperature that we take for granted. Any number of so-called primitive peoples could boast of permanent outdoor masonry or earthwork ovens. Adobe ovens survive in daily use in the Andes. I recently ate bread baked in an outdoor communal oven in a Swiss village in the hills above Ascona. In Israel, religious families still take pots of cholent, the bean dish that is the cassoulet of the Jews, to a communal oven just before the Sabbath and leave it to bake slowly until they retrieve it for lunch the next day.

I have been unable to determine if housewives on the isle of Guernsey in the English Channel continue to carry a similar dish, Guernsey bean jar, to their village oven. On Atlantic Avenue, in Brooklyn, however, one can get a taste of what this old-fashioned community oven was like. Under the sidewalk in front of the Near East Bakery, a long and shallow brick, gas-fired cave of an oven bakes Levantine meat pies. The baker pulls out fresh batches at lunchtime on a long-handled peel, the oar-shaped wooden tool that was the emblem of medieval bakers. When you eat one of those pies, it is easy to

imagine that you have stepped back into the village life of an earlier time.

The transition from communal to domestic ovens has taken quite a while and it has not been complete. Commercial bakeries still bake most of our bread. Home ovens will also do the same job, but they are primarily what the French call *fours de cuisine*, kitchen ovens designed to perform a multiplicity of tasks, one of which is a relatively new wrinkle in the long history of ovens: roasting large cuts of meat.

Until the last century, the leading method for roasting legs of lamb and loins of pork was to turn them over an open fire on a spit. As recently as 1892, Lucien Tendret, the great gastronomic writer, insisted that the antique spit was the instrument of choice for roasting. Ovens, he argued with some real merit, tend to dry out the meat: "To claim otherwise is a heresy condemned by all the councils of the Fathers of the table." Tendret had lived through the technological change from the magnificent, clockwork spit mechanisms of the past to the far more accurate roasting ovens whose descendants we take for granted today. He contended that fat dripping from meat in the enclosed space of an oven eventually vaporized and reattached itself to the meat as a burned taste. To avoid this defect (chimerical though it may seem to our perhaps degraded palates today), he was willing to put up with the notorious difficulty of accurate spit roasting. Those glorious machines (one marvelous example of which is on display at Mad Ludwig of Bavaria's fairy-tale nineteenth-century castle, Neuschwanstein) apparently required a special knack.

That is why Brillat-Savarin wrote that "men learn to be cooks but they must be born knowing how to roast." Nevertheless, spit-roasting does survive, in miniature, electrified form as an adjunct to some outdoor barbecues, while the Greek gyro machine, now in vogue in this country, is a vertical spit. Even so, the roasting oven has overwhelmingly carried the day against its more picturesque antecedent.

The man behind this little-known revolution in the kitchen was Benjamin Thompson of Woburn, Massachusetts, who emigrated to Europe and became a world-famous scientist under the name of Count Rumford. About 1800, he experimented with a

cylindrical metal roasting oven. Rumford was generally occupied with the problem of making kitchens more thermally efficient, and with his oven, he was able to save energy and, he argued, to cook better as well. To prove his point, he conducted what may have been the first modern experiment in home economics.

Rumford cut two legs of mutton of equal weight from the same carcass. Without explaining to his kitchen staff that something special was afoot, he had them roast one leg on a spit and the other in his new oven. The oven-roasted leg came out weighing 6 percent more than its spit-roasted twin. A subsequent tasting is supposed to have demonstrated that the oven produced juicier meat than the spit.

Since then, the roasting oven has triumphed and evolved into an even more efficient instrument. Lightweight insulation and thermostatic heat give any modern amateur chef more exact control of roasting and baking than the chef Carême had when he cooked for Napoleon and Talleyrand. Our ovens are not, however, perfect. Generating large amounts of heat, they turn our kitchens into miniature infernos on summer days. And they must be preheated for fifteen minutes or so if they are to reach the temperature we call for with a flick of the dial. (Incidentally, it does no good to dial up to 550 degrees when you want to preheat most ovens to, say, 350 in a hurry, because the typical thermostatic provision for preheating has the oven burner running full blast anyway, until a temperature somewhat above the designated one is reached. This "preheat overshoot" is built in to account for a heat loss when the oven door is opened for the food to be put in.)

Absolutely cool and instantaneous oven action can, of course, now be obtained with microwave devices. But some experts are still worried about radiation leaks from microwave ovens, and these "radar ranges" do cost more than their somewhat limited usefulness merits (they do not, for instance, brown meat). Nevertheless, they do look like what you might call the wave of the future. Some day soon, they or their modified versions will no doubt replace thermal ovens. And future historians will have to explain what Harry Truman meant when he said, "If you can't stand the heat, stay out of the kitchen." By then, of course, there may no longer be large cuts of meat.

Cholent

This is an adaptation, with eggs added for an Israeli touch, of a recipe in *The Best of Jewish Cooking*, published by The Dial Press in 1974.

1 cup dried lima beans
3 tablespoons rendered chicken fat
3 medium onions, peeled and chopped
2½ pounds beef brisket or chuck
2 teaspoons salt
4 large potatoes, peeled and quartered
½ cup raw, coarse barley
1 clove garlic, peeled
Black pepper
2 teaspoons paprika
1 bay leaf
6 uncooked eggs, in the shell

1. Soak lima beans overnight in a generous amount of water.
2. Drain the beans the next day and set aside.
3. Heat the chicken fat in a large, heavy saucepan or Dutch oven. Sauté onions in hot fat until translucent. Remove and set aside.
4. Brown the meat in the remaining fat until all sides have turned a rich, caramel brown.
5. When meat is completely browned (beige doesn't count), but before it burns, remove the saucepan from the burner (or turn the burner off if you cook with gas) and pour the beans over the meat. Next come the potatoes, then a layer of barley, then the onion.
6. Add garlic and sprinkle on the seasonings. Finally, add enough cold water to cover the ingredients. Arrange eggs in the water.
7. Cook over low heat for one hour. Near the end of this period, turn on oven to low, that is, set the dial at whatever is its lowest marking. Traditionally, cholent is put in the oven, covered, before sundown and left to cook slowly until lunchtime the next day.

Yield: 6 to 8 servings

Raymond Sokolov's most recent cookbook is The Saucier's Apprentice, *a guide to French sauces.*

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The Bubble Trade

by Horace Beck

In the lesser Antilles, where there are few opportunities for economic betterment, success in smuggling leads to respect and status

In the Lesser Antilles, an island chain in the West Indies that arcs southwestward from Puerto Rico to the northeast shoulder of South America, smuggling is a way of life. The inhabitants of these islands are mostly of African stock, the descendants of slaves brought years ago from the coastal areas of present-day Nigeria and Dahomey. Despite some interbreeding with the Carib Indians and with the small populations of Scots and Irish that had settled there, their culture remained predominantly African. Following emancipation in 1834, and the abandonment on some of the islands of the great estates on which they once worked, these people evolved a society based partly on folklore, cults, and poverty.

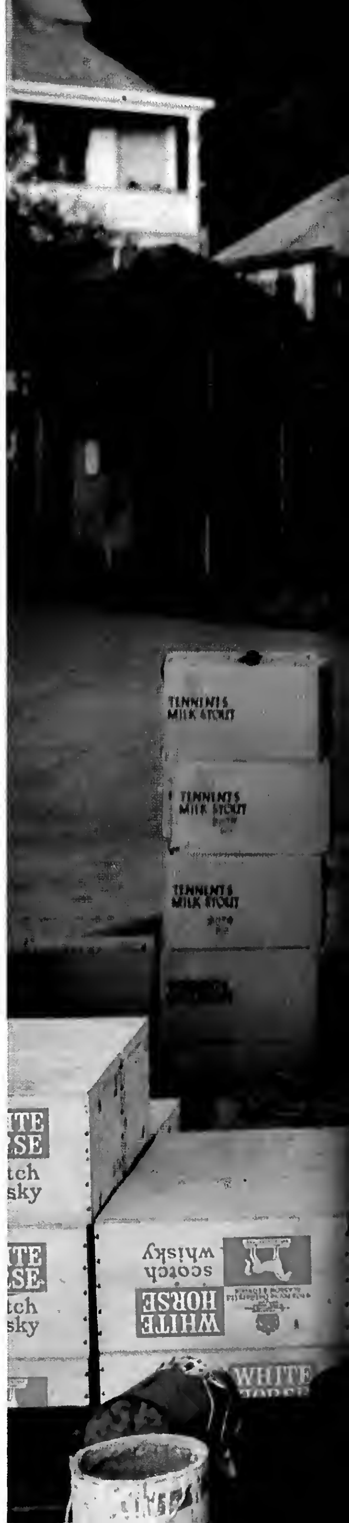
Theirs is mostly a subsistence economy—they grow some vegetables and fruits or gather them in the wild. Fishing provides their chief source of protein. Opportunity for economic advancement is very limited and the possibilities for change are few—unless one can enter politics, where the rewards are astonishing. Money is scarce and knowledge of business management is rudimentary. For the most part, the West Indian can look forward to owning a rum shop or a small trading schooner or to boat building, goals only a few can achieve.

Despite this, the West Indian is anxious to advance his status. Since he cannot easily improve his financial situation, he attempts to increase the respect accorded him by the community. But because it is so difficult to gain respect through traditional economic means, many West Indians have entered the smuggling business as a way to gain both economic and social status. Not only is smuggling beneficial to those who trade in contraband but it also makes goods available to friends and neighbors at prices they can afford. Some of the products smuggled to various islands would be legally unobtainable due to protective laws and tariffs.

For both economic and geographic reasons, it is no accident that smuggling has proliferated in these islands. At the northern end of the chain, Saint Martin and Saint Barthélemy (Saint Barts) are duty-free ports where goods can be purchased at a fraction of the price charged elsewhere. Tariff rates and prices vary from island to island, and smugglers commonly buy on one island and sell on another that has a higher tariff.

In the Lesser Antilles, the wind usually blows from the east. The islands break the force of the Atlantic seas and gales, allowing smugglers to sail in the relatively protected waters off leeward shores. Sailing from one island to another is usually rapid and smooth. Almost any indentation on the leeward coasts provides the seclusion necessary for the safe discharge of cargo, which smugglers generally store and distribute in the security of the nearest rum shop.

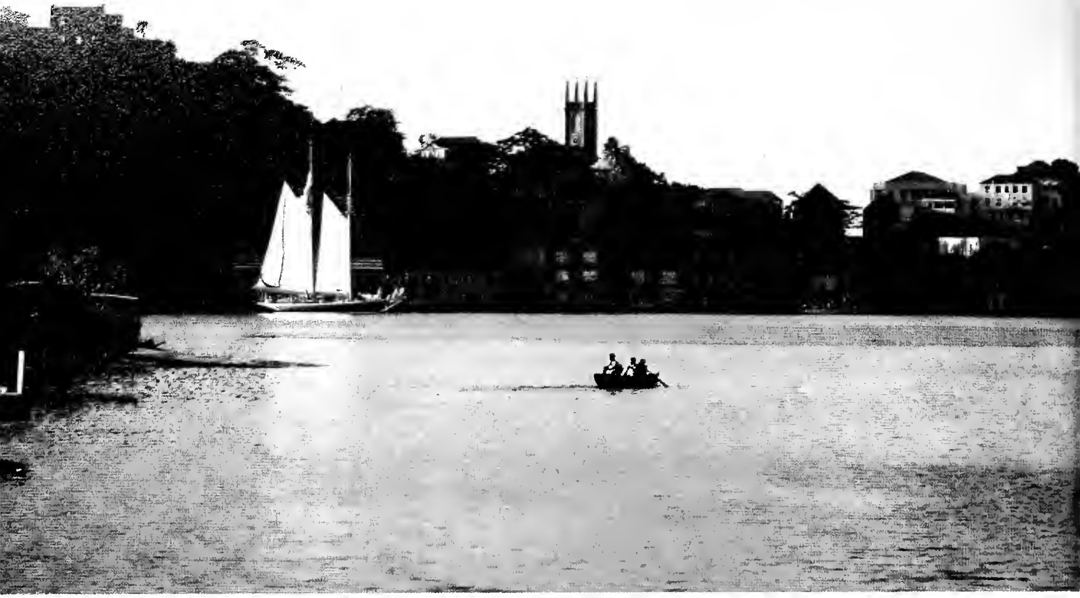
No one knows the exact number of



Much of the contraband in the West Indies originates from Saint Barts, a duty-free port. Liquor, one of the principal smuggled goods, is transported to other islands by sailing vessels.

Jane Beck


WHITE HORSE
scotch whisky



Large sailing vessels such as this schooner frequently take on contraband in Saint George's, Grenada, for transport to Venezuela.

people who smuggle, but it is probable that up to 80 percent of the male population have taken part in the trade at one time or another; 5 or 10 percent pursue it full time. Of all the imported goods sold on the islands, perhaps 30 percent are contraband. And most of the area's cigarettes, whiskey, and rum are smuggled from island to island.

The implications of smuggling go far beyond traditional economics or providing communities with illegal goods. West Indians are extremely serious about achieving respect and have developed a straightforward value scheme for recognizing and evaluating it. Successful smuggling plays a great role in this scheme. The concept of courage is foremost. A man is either brave or cowardly, and a coward only invites disdain. The desire to be thought of as brave is so strong that expressions such as "please" and "thank you" are seldom used because they indicate weakness. One may demonstrate courage in a number of ways—by facing danger, by demonstrating physical strength, or by exposing oneself to, and enduring, supernatural powers.

A second and closely related value is cleverness as opposed to intellectual brilliance. Albert Einstein would have been shown little respect in this culture but a clever thief is admired. The thief shows courage in risking exposure and cleverness by not getting caught.

Sexual prowess is another important means of achieving respect. The man who can seduce many women must be physically strong, clever, and brave enough to risk the wrath of irate husbands and lovers. And his offspring offer irrefutable testimony to these traits. One of the most famous men on one island achieved his reputation by sailing a whaleboat in the night across five interisland channels, accompanied only by a woman. His respect stemmed from his claim that he had had sexual intercourse with the woman three times in each channel.

Fishermen in small, open boats often smuggle to supplement their income. The contraband is usually concealed under the day's catch.

Yet another cultural consideration is a deep-seated belief in the supernatural world. The dead play a large part in the attitudes of the living—advising, aiding, and directing. When the dead are needed, they are called through the rituals of obeah, a type of sorcery used by West Indians to assist them in achieving an objective, be it to help or to hurt someone.

Within the West Indian economic and cultural framework, there is a day-to-day flow of tranquility, interspersed by short spells of intense physical activity that often involve the kind of danger that brings respect and status. Ordinary days revolve around harvesting coconuts and vegetables, milling cassava, fishing, and turtle hunting. The principal recreational activities are cock fighting, dog baiting, and playing cricket. During these periods of calmness many of the men spend long hours with their neighbors recalling sporadic moments of danger when courage and cleverness were at a premium. Most of these times focus on the "bubble trade," the name West Indians have given to smuggling because contraband occasionally includes sparkling wine.

The small, ancient, and beamy sailing vessels used in this trade generally have rotting hulls and lines, patched sails, and engines with defunct cylinders. Most of them leak and their rusted exhaust pipes are apt to fill the cabins with carbon monoxide. Their "galley" is usually a brazier, which not infrequently sets the ship afire. The boats lack fire extinguishers, life lines, life preservers, radios, radio direction finders, logs, compasses, charts, watches, or sextants. The windlass is usually inoperative and the cable too short to anchor in many places. The boats are kept afloat only through the combined efforts of cockroaches and termites holding hands and wheezy, worn-out pitcher pumps, which, in Sisyphean fashion, recycle the Caribbean through the hull. To make matters worse, almost no aids to navigation, such as lighthouses or buoys, exist in the Lesser Antilles. Finally, the vessels are so overloaded, they float on their deck beams.

Such a dearth of equipment or maintenance seems to be of little concern to the smugglers. They are not accustomed to safety devices and few know how to navigate. Radio direction finders have almost no stations on which to home and should a boat have a radio and send out a "mayday" for assistance, only a foreign yacht would answer the call, for sinkings in the West Indies are so common as to elicit little interest on the part of the authorities. Moreover, no one transporting contraband wants to be rescued by the coast guard.

To the West Indian, courage lies in undertaking the long voyage and encountering the natural and supernatural hazards of nighttime sailing. In the dark, squalls rise quickly and without warning, sometimes washing sailors overboard; bearings are easily lost; and an unmarked coast in the murk of rain is a constant danger. The night also brings ghost ships, phantom lights, *jabless* (a kind of she devil), and spirits. One man recounted an all-night chase by a phantom longboat manned by ghostly pirates seeking the blood of his crew. The dangers of sailing at night are increased by the presence of obeah, which works best in the dark.

Or so West Indian folklore has it. Actually the dangers are slight if one does not take into account the poor condition of the boats. The smugglers' course is in the lee of the islands; it is only while crossing the channels that the boats feel the weight of the ocean swells and the full force of the heavy trade winds.

Most of the island governments pay no attention to smuggling. Martinique and Guadeloupe, however, are exceptions; here smugglers are hunted with a vengeance. Contraband boats passing these two islands must keep out of sight of land. Not only does this make for hazardous navigation but by venturing so far out, skippers leave the protective lee of the islands and the boats' rotten canvas

and shaky cordage can ill bear the weight of the trades. Also, by going offshore, vessels are forced to sail against the wind to return closer to the islands. As a result, they pound, leak, often become lost, and sometimes sink.

One tale that West Indians frequently retell concerns this very hazard. Several years ago a small sloop set sail for Saint Barts from an island about four hundred miles to the south. Various members of the community entrusted the skipper with several thousand dollars with which to purchase contraband. Some of the money represented not only the life savings of the people involved but also a degree of courage, for no West Indian wants to lose money or face. The best the sloop could hope to do was about a hundred miles a day, with an additional day for procuring and loading the cargo, but so eager were the people of the community, that after five days, they set a watch on a high hill and eagerly scanned the horizon. A week went by and the boat did not appear. The islanders began to worry; and after ten days their worry turned to anxiety. Just before dawn on the twelfth day, a sail that looked like that of the sloop was

Cock fighting is a popular sport on Saint Lucia and Martinique. Before each fight on Saint Lucia, handlers lick the birds' claws to prove that poison has not been daubed on them.

sighted low down in a squall. The watch thought the boat would come in after dark. But she did not come that night. By the following afternoon, when everyone was sure all hands had "gone bottom," a call came from Nevis, three hundred miles away. The message was that the vessel was at anchor there and that the crew were flying home. On their arrival, they were not well received.

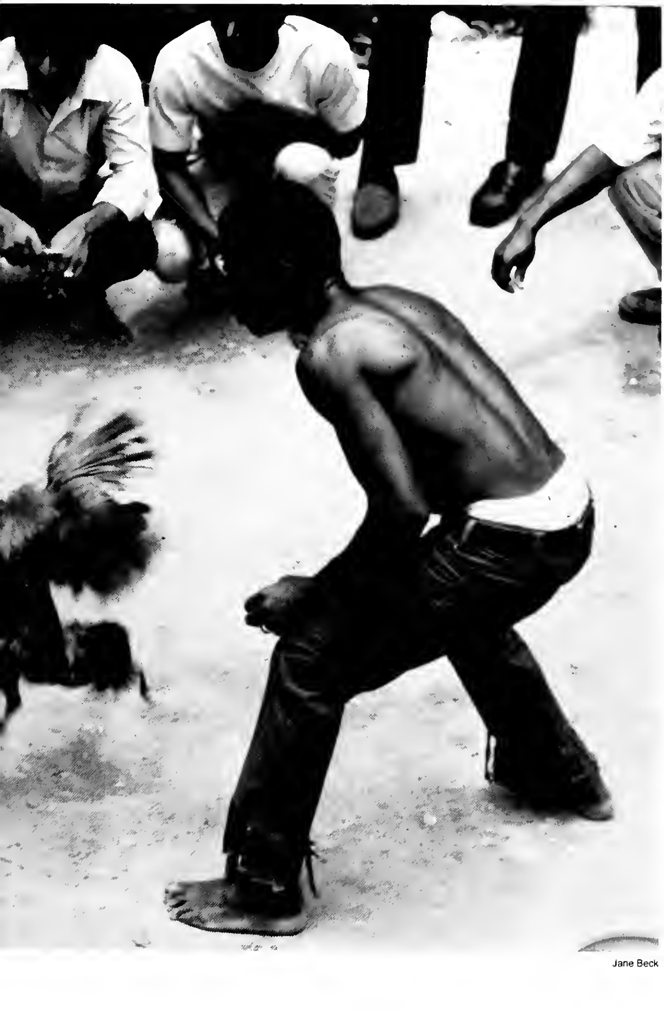
West Indians do not like to accept the blame for any misfortune, so the skipper and crew had to provide a reasonable explanation. They said that the vessel had arrived on schedule at Saint Barts, taken on its cargo, and begun the return journey. But far off the lee shore of Guadeloupe, the wind backed south and blew hard, bursting the main sail and blowing out the jib. The engine could not push the boat against the waves and wind, and before long the fuel supply was exhausted. Finally, in the gloom of a stormy dawn and five days behind schedule, they raised their home island. But before they could make land, the weather turned worse, forcing them to run before the wind away from the island. By the next morning, the gale had blown out the rest of the sails and the boat began to drift down on a revenue cutter—but not before the crew threw all the contraband overboard. The cutter towed the disabled but empty boat to Nevis. The crew evaded all questions asked by the revenue officers and returned home. This demonstrated raw courage. The islanders were satisfied—the men were brave.

I am convinced that a sloop with sails in tatters could not run three hundred miles in thirty hours. I believe the boat probably never reached Saint Barts; that it was disabled off Guadeloupe, where it was rescued by the cutter and towed to Nevis. When I learned that this was the skipper's first voyage, I became even more skeptical of the crew's story.

Another tale recounts the 25-day voyage of a large vessel from Saint Barts to her home island, a distance of less than five hundred miles. The crew said that they had approached from out of sight of land, and without any knowledge of navigation, had hit their island dead on. Closer investigation revealed the true story. They had missed their island by three hundred miles, raised South America, sailed back, misidentified another island, and finally blundered home.

Those engaged in the bubble trade face yet another hazard—revenuers. Sometimes, officials are bought off in advance or have a part share in the vessel or, in rare cases, feel that the trade benefits the island or that the protective tariffs are unjust. Still, there are a sufficient number of officials who for various reasons—personal spite and malice, insufficient bribes, a misguided sense of duty, or hopes of early preferment in their calling—feel they must enforce the laws. To be willing to risk capture by these authorities, no matter how minimal that hazard may be, is to display courage. To escape capture requires cleverness. The methods used often have morbidly humorous overtones.

Years ago a boat named the *Artful Dodger* was about to unload cargo when a spying revenue officer was found hiding under a rowboat propped up on shore. The props were kicked away and the captain and mate sat on the dory and regaled the revenue officer with a running account of the contraband being discharged. When all was over, the crew lashed the rowboat to the beach and sailed away.



Jane Beck

James R. Smith

The names given to boats in the West Indies reflect not only the desires of their owners but also their belief that vessels will be assisted by supernatural powers.

Recently the police commissioner of Grenada decided to put a stop to the only business on the island of Petite Martinique—smuggling. He ordered his constabulary to go to the island and search it. His men, however, were so sure that the smugglers would harm them that they would not carry out the orders. In a rage, the commissioner went to the island himself, where he was met by a polite delegation and invited to a party. Asking what the event was, the commissioner was told that the people were going to celebrate his death and had already dug his grave. He quietly withdrew and smuggling remains the main enterprise on Petite Martinique.

Not all smuggling stories have such an amusing end. One of my informants told me of an adventure he had while working as a cook on a bubble boat. Having just discharged the cargo, the crew began to sail for home when a revenue officer stopped the boat and boarded her. After a fruitless search for contraband, the officer demanded some food, specifying that it had to be hot. The cook told me that he fried up some fish and sprinkled it with bitter powder. As the officer prepared to leave after having finished his meal, he told the boat's captain, "keep away from these waters." The captain assured him that their paths would never again cross. Three-quarters of an hour later, the revenue officer was dead, poisoned by the bitter powder.

Although the bubble trade can be a rough game, many smugglers try to avoid trouble by resorting to obeah. Crews anoint boats with various oils, powders, and potions to make them swift, to ward off bad weather, to protect them from wraiths and sea devils, and to make them invisible to the coast guard. Some smugglers place thorns from a silk-cotton tree under the boat's tiller, similar in concept to putting a burr under a horse's tail to make it gallop faster. There is a belief, however, that such doctored vessels will capsize at midnight; thorns are thus ordinarily used only for short hauls. A more sinister concoction, which is spread on the vessels, is a salve said to be made from human livers and other organs collected from hospital morgues.

Obeah is a superstition whose strength has not suffered with the passage of time. I was told the following story in all seriousness. Although the events could hardly be possible, it is significant that some West Indians believe in the authenticity of such tales. A few years ago, the police, suspecting that a boat was engaged in the bubble trade, slipped seven men armed with flashlights and rifles aboard her to trap the crew when they came aboard. Learning of the surreptitious activity, the captain sought out an obeah man, who promised to manage the matter. The crew never boarded the boat, but the waiting police suddenly saw the windlass turn and crank in the anchor chain. Then the sails were hoisted and the boat began to gather headway. The next morning the captain went aboard and found seven rifles and the flashlights but no police. They had long since jumped overboard and swum ashore.

Smugglers also call upon obeah to deal with informers or those who happen upon a bubble boat in the midst of being unloaded. The problem can usually be dealt with by paying off the intruder, whose demands are usually low—a carton of cigarettes, a bottle of rum. But sometimes they become exorbitant and then smugglers will resort to violence or threaten obeah. In the long run, obeah is the most effective deterrent.

Long ago, a woman in Dominica discovered the *Granville Lass* unloading in a quiet bay one night and insisted on about a third of the cargo to keep her from informing the police. The captain gave her a couple of bottles of rum and threatened her with instant death if she did not leave. The woman departed but returned with the police thinking she would receive a reward. The police captured and jailed all but one man who jumped overboard and escaped. Anxious to free his companions, he contacted an obeah man who agreed to help. This conjurer advised each prisoner to say "freedom" before the judge at the arraignment and the escaped man to say the same word to the woman.

The next morning each of the accused pleaded freedom and the judge immediately dismissed the charges. After the last man had been released, the man who had escaped stood up in the courtroom, pointed a finger at the woman informer, and said "freedom." Her lower lip suddenly began to grow until it reached an enormous size. Henceforth, she was considered the ugliest woman in Dominica and her village became known as *pays bouche* ("village of the mouth"), a name used to this day.

The police are not exactly indifferent to the wealth derived from smuggling. Once, I was watching some smugglers unload a cargo and carry the contraband to a rum shop for storage. As a police boat approached, the smugglers worked faster and faster in an effort to hide as much of the cargo as possible so they would not have to give the policemen a large share of the goods. Fortunately for the smugglers, they managed to put all their booty in the rum shop. All that was left in the vessel's holds were fish that the smugglers had used to conceal the contraband. The police, in their starched white uniforms, futilely searched through the fish.

After a successful voyage, a smuggler is a desirable catch for any woman. He has demonstrated his cleverness, has change in his pocket, and liquor, perfume, cloth, and various pretties in his sea bag. Success with women is proof of his virility. Sometimes this sexuality can lead to serious problems. Captain B. was such a successful smuggler that he had two mistresses as well as a wife. One of his mistresses gave him some money with which to buy her some contraband rice. When the captain returned from his next voyage, he sold all the cargo but did not give the mistress any rice. Instead, he gave presents to the other mistress. An-

Even though they may profit greatly from their trade, many smugglers continue to live in ramshackle huts. In this way, they hope to avoid suspicion by the police.

James R. Smith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gered, the first mistress informed the authorities in Dominica of Captain B.'s activities and told them when he was coming. When he arrived on the island, his vessel was seized and all hands flung in jail.

The owner was forced to pay not only part of the value of the vessel but the fines of the crew as well. Captain B. sailed for home with empty holds, and when he arrived the owner had two checks ready—one for the crew's pay and another for the captain's severance. He also had informed the captain's wife of her husband's activities and she promptly left him. The captain's two mistresses also severed their relationships with him.

Although smugglers make a good profit from their trade, earnings are tainted and must be rapidly disposed of. Tradition has it that unless a smuggler spends half of what he receives, he may well be destroyed by the devil. The West Indian admires the spender and rewards him with respect. Conversely, invectives are the reward of the saving man.

Small fortunes have resulted from the bubble trade. The richest man on one island is said to have made in excess of a million dollars. But to display conspicuous signs of such wealth is to court disaster. Those who have profited by the trade must continue to live in their meager houses and dress like the poorest fishermen. A change in life style could bring hard questions from the police. The successful smuggler is thus caught in a social trap and must dispose of his wealth in ways that make its source look legitimate. If he spends his money, he is in constant danger of being arrested; if he hoards it, he is subject to the criticism of his neighbors. Walking this thin line, the only real respect he receives is through his courage and cleverness while on an actual smuggling voyage. □

Most smugglers sail their boats along the Lesser Antilles without the aid of navigational equipment. Often in poor condition and overloaded, the vessels easily founder in a storm or when out of the protective lee of the islands.

Jane Beck

A Pelican Synchrony

by Fritz L. Knopf

Survival of chicks is a reward for meshing breeding activity; good fishing is a reward for nesting in colonies

Birds nesting in colonies pose some intriguing questions. Some advantages to colonial nesting, such as mutual defense against predators, seem obvious, but so do some disadvantages. Why, for example, build nests in localized, high densities, which appear to maximize competition for nest sites and materials? To try to find some answers, I decided to do a field study on the spectacular white pelican, which nests colonially on a remote island in Great Salt Lake, North America's inland sea.

The North American white pelican (*Pelecanus erythrorhynchos*) is one of six recognized species of pelicans found throughout most of the world. Five of the species are basically white and live in freshwater environments; the marine-living brown pelican is the exception.

Unlike the brown species, the white pelican has not experienced the deleterious impacts of pesticide contamination on eggshell thickness and reproductive behaviors. Levels of DDT and its metabolic derivatives, DDD and DDE, have remained comparatively low in North American white pelicans and their eggs. This disparity in pesticide contamination levels between the two species is due to their nesting site locations. White pelicans nest primarily along the shores of lakes in near-desert and

A chick delves into its parent's gular pouch for a meal of regurgitated fish (left). By the time of fledging, the chick will be almost 20 percent heavier than an adult. The extra weight enables young pelicans to survive the period when they must learn to secure their own food. White pelicans nest in discrete colonies on Gunnison Island, Great Salt Lake, Utah (below). Islands free of mammalian predators, with level, open areas for takeoffs and landings, are required for pelican colony formation.

Fritz L. Knopf

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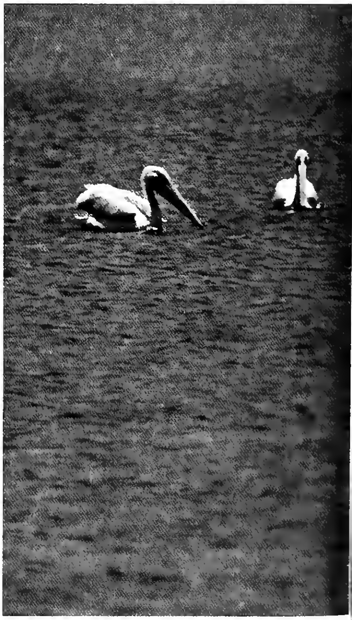
northern prairie regions, which are not agriculturally or industrially developed. Brown pelicans nest along the heavily populated and developed western and gulf coasts of the United States, where pesticides (and other wastes) leach into the ocean from agriculturally developed land.

Historically, the continental population of white pelicans declined with the draining of the extensive wetlands of the northern prairies. By the early 1960s the population had stabilized at just over 30,000 birds. A 1972 survey indicated this population nested at fourteen sites on the continent. A fifteenth site was added in 1976 with the colonization of islands in Honey Lake, California, by an estimated 2,000 birds.

A majestic bird, the North American white pelican has a wingspan of about nine feet, only slightly smaller than our largest native bird, the California condor. The large wingspan, along with a relatively light body weight of fourteen pounds, is an adaptation for soaring on thermal air currents; an ability that aids the birds in ranging widely between food resources by reducing the need for energetically costly active flight.

The major morphologic feature of pelicans is their large gular pouch, which is used as a dip net to scoop up fish. This distensible pouch has two other functions. By vibrating one of the pouch's structures, a pelican can cause the tongue to flutter. The fluttering promotes evaporative cooling from the inner surface of the pouch, which in these birds is an energetically more efficient cooling mechanism than panting. The pouch also plays a role in the social life of pelicans. Distension and lateral display of the pouch, accompanied by soft grunts, occurs when mated pairs meet after an absence. Such behavior appears to be an essential part of the mate recognition process.

The first of the more than 5,000 white pelicans that nest annually in the Great Salt Lake region return to Utah in early March from their wintering grounds in western Mexico,



Using rising thermal air currents for lift, pelicans circle to gain altitude. Enroute to their feeding grounds 40 to 60 miles away, birds from the different colonies on Gunnison Island may join together and function as feeding flocks upon arrival at their destination.

soon after the ice melts in the extensive marshlands along the lake's east shore. The pelicans visit the traditional nesting site shortly after their spring arrival and lay their first eggs at the beginning of April. Late arrivals come into northern Utah and lay eggs through the end of June.

On 150-acre Gunnison Island in Great Salt Lake, pelicans nest in discrete colonies on low, flat areas, avoiding steep and rocky slopes. Colonies range in size from the definable minimum of two nests to more than six hundred nests, with as many as thirty-five colonies on the island in a given year. Nests within a colony average slightly more than a half yard apart, and the nests of one colony are often only a few yards from nests in another colony.

Within a colony, the reproductive activities of pelicans are highly synchronized. Egg laying, hatching, and fledging of chicks, for example, occur within cycles of five to nine days for all nests. In contrast, reproductive activities in the pelican population as a whole are highly asynchronous. Progressive stages in the reproductive cycle are often separated by four to eight weeks in neighboring colonies. On many days I could easily observe the entire spectrum of reproductive activities—from pair formation through incubation and brood raising—by scanning different colonies on the island.

An aspect of the colonial nesting habit of birds almost totally ignored by researchers is colony formation. With the white pelicans, I found that sexually aroused, unmated birds of both sexes are especially attracted to those displaying courtship behaviors. The result is a flock of courting birds. With each succeeding day, individuals in the courting flock acquire mates, defend territories, construct nest mounds, and ultimately lay eggs, while birds seeking mates continue to join the flock for an additional five to nine days after the flock has settled in a given site. (The timing of these events assures that reproductive synchrony is maintained throughout the nesting period.) Coming together as a flock, the courting birds are, in effect, the precursor to the establishment of a colony of nesting birds at the site. Different flocks, and then colonies, are established as new birds arrive in the area. There may be a half dozen or more courting flocks on Gunnison Island in any week during the breeding period.

When a sexually active female first enters a courting flock she charges among the massed bodies of unmated males loitering on the periphery. Jabs delivered by the bills of the males impede her progress until she stops and assumes an elaborate bow posture. The closest males respond to her bow with a more subtle bow and overt aggressive behaviors by the surrounding birds diminish. After the exchange of bows, the female usually recommences her attacklike movement toward the center of the flock until she is again forced—or chooses—to stop and bow. Her movement through the flock, together with the high-density social environment she encounters, seems an essential, sexually excitatory stimulus. Males attempt to keep up with a female, and through the course of a few days, one male successfully maintains his position by rebuffing other males and a pair bond is established. Usually neither bird leaves the flock during this period, even to feed.

Bow posturing appears to be a sexual, not an appeasement, behavior. A male only bows in response to a female doing so first, but her bowing stimulates him to do likewise. An over-all effect of this posturing is to reduce the level of aggressiveness be-

J.C. Stevenson, Animals, Animals

Feeding flocks of white pelicans line up to herd fish into shallow water. Working the fish, the birds form a semicircle that blocks the escape of their prey. Fish are then scooped up in the birds' pouches. Wintering birds in San Diego Bay, California, shown.

Fritz L. Knopf

White pelicans seldom raise two chicks successfully; those that do, tend to be neighbors. The suspicion is that they are older, more experienced birds. Adult on right nest is merely scratching its wing.

An adult incubating its eggs kills a wandering chick with a single blow to the head. Such incidents are rare as the synchrony of breeding events in a colony usually insures the breakdown of territorial nest behavior by the time chicks are old enough to stray from nests.

Fanning their pouches and emitting soft grunts, mates exchange greetings at the nest as one prepares to relieve the other of tending their offspring. In 24 hours, they will again switch.

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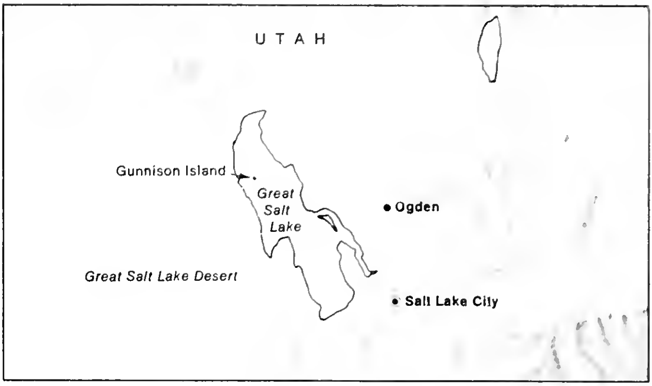
tween the two. After pair formation and nest site selection, the bow of the female becomes the invitation for copulation.

Once paired, the two birds progress farther into the center of the flock, until they encounter other pairs already defending their nest sites. The newly mated birds move within about a half yard of the territorial birds, select, and then defend their own nest site. Substrate features generally receive little, if any, consideration in the nest site selection process; proximity to other pairs appears to be the major criterion.

Aggressive behaviors between pairs of birds are frequent and violent during activities associated with courtship, mating, and especially, defending a nesting territory. I noticed, for example, that the rate of aggressive encounters per pair of birds (they respond together to challenges from neighbors) peaks at better than 200 encounters per hour during the initial period of nest-site defense.

During the breeding season, white pelicans have an unusual morphological structure that I speculate directs an agonistic blow to an area where it will do the least harm. Both males and females develop a hornlike, deciduous maxillary protuberance, which drops off during egg incubation—by which time territorial boundaries have been resolved. This structure seems to serve as a target for aggressive jabs, with 95 percent of all agonistic blows being directed at the "horn" on top of an opponent's bill. Just as mountain sheep perform a ritualized combat of head-on clashes and possess highly pneumaticized skulls to absorb such blows, pelicans resolve their conflicts without excessive injury to participants.

Once the selected nest site has been successfully defended, the pair copu-



late for four to five days. The first egg appears on the fifth day. On the fourth or fifth day the male leaves his mate to visit feeding grounds in marshes along the eastern shore of Great Salt Lake, forty to sixty miles away, and returns three days later when the two-egg clutch is complete.

As more males temporarily leave the courting flock during egg laying, the density of the flock is reduced, the intensity of excitatory stimuli associated with courtship, copulation, and territorial nest defense declines, and a greater proportion of the flock assumes the appearance of an established colony of incubating birds. The flock becomes less attractive to later arriving, unmated birds, which congregate at other sites where courting birds are more in phase with the newcomers' physiological state.

Pelicans attend their nests continually throughout incubation (about 30 days) and until the chicks are three to four weeks of age. The male takes the first turn incubating the eggs, enabling the female to go off for her first meal since the pairing process began. During incubation, the male and female exchange places on the nest at 72-hour intervals. They switch to a 24-hour schedule after the eggs hatch. A bird coming to the island to relieve its mate lands near the colony, preens for a moment, then walks directly to the nest. After exchanging bows and greeting behaviors, the birds switch places; the bird from the nest walks outside the colony, stretches and preens briefly, then flies to the distant marshes to feed.

At four weeks of age the nutritional demands of the chicks require the full-time efforts of both parents to feed them. Chicks are often left to wander about unattended as both parents go off to hunt for fish (mainly carp). The chicks are capable of flight at about twelve weeks. At fledging, a chick may weigh as much as 20 percent more than its parents, this excess weight likely representing a metabolic reserve to buffer the lean period when the chick must learn to secure its own food.

During late incubation and the nestling period, both adults undergo a molt of their head feathers. The flowing, white crest feathers of the nuptial plumage are replaced by short, gray or black plumes. The striking aspect of this new plumage is that virtually no two adult pelicans look exactly alike. When pelicans return to the island to feed older chicks, they return to the site of the colony and wait to be approached by their own chicks. The variability in plumage on the heads of adults may provide visual cues that facilitate the initial recognition process for chicks. This is similar to the system used by royal terns; but in these terns, the chicks display the highly variable plumage patterns and the adults visually screen the nursery for their offspring.

One of the more intriguing questions about bird colonies is why they tend to be synchronized. Recently, there has been much speculation that colonial nesting and synchrony within a colony promote the opportunity for birds to share information on the location of food resources. Birds that nest in colonies typically exploit food resources that occur in variable

An adult in breeding condition sports a "horn" on its bill that serves as a target for the agonistic jabs of other colony members. The horn, a little the worse for wear, will fall off during the egg-incubation period.

William B. Robinson; Animals, Animals

abundance at unpredictable locations. This "information center" hypothesis has received some support from recent work with great blue herons in British Columbia. Observations of these herons revealed that birds on neighboring nests exchanged places with their mates at about the same time, and birds leaving the colonies departed together in small flocks. This information cannot be directly applied to the situation in pelican colonies, however, since nest exchanges are not synchronized between neighbors in a colony. Exchanges in a pelican colony occur at only a third of the nests each day.

I believe, however, that coloniality does enhance the ability of white pelicans to locate and exploit food resources. The white pelican is a social feeder—small feeding flocks work cooperatively by forming a line and herding schools of fish into shallow water where they can be captured, dip-net fashion, with the pouch. When relieved at the nest by its mate, a pelican flies directly from Gunnison Island toward the feeding grounds, joining other birds enroute. Upon arrival at the feeding grounds, the bird will either join other pelicans already foraging or select a new foraging area. Being in a feeding flock likely facilitates selection of a good foraging site, as inferred from the observation that birds rarely leave to feed on their own. By nesting in a colony, pelicans can readily join feeding flocks, and individual members, especially younger ones, can benefit from the combined fishing experiences of all birds in the flock.

For pelicans, synchronization of reproductive events within a colony has at least one observable adaptive value. When parents leave their chicks after the nestling period, the chicks are still awkward and uncoordinated. They wander from the nest site and, on extremely hot days, move to the island's shoreline, where they stand in the water as a means of regulating their temperature. In an unusual instance, I watched such a chick wander within reach of a territorial pelican that was still incubating its eggs. The adult struck the chick on the top of the head and killed it with a single blow. Survival of chicks when they first leave the nests is dependent upon a synchronous breakdown of adult territorial behavior.

Nests in small colonies exhibited a mean productivity similar to that of large colonies. Pelicans, which select their nest sites based upon the social environment, do not appear to benefit from belonging to a larger colony. The social environment (at least as far as its impact upon successful nesting behavior) seems limited to the interactions between neighbors.

Pelicans may be very selective of their neighbors, however. Although the average productivity of a nesting attempt is only .85 chicks, about 11 percent of the attempts do result in both eggs of the clutch leading to fledged chicks. Interestingly, more than 70 percent of the nests producing two chicks are situated near or next to nests from which two chicks also fledged. It may be that older birds more experienced in raising chicks tend to select similar neighbors.

The colony formation process of pelicans forces us to dispel some historical opinions about the species. Although these birds tend to nest on the same islands in subsequent years, the predominant role of the social environment in the selection of a nest site implies that white pelicans are capable of establishing a breeding colony wherever a sexually active flock encounters a barren, predator-free island with open, flat areas, which the birds need as runways for their awkward takeoffs and landings. Such a colonization occurred in a reservoir near Fort Collins, Colorado, in the early 1960s, and at Honey Lake, California.

The future of the white pelican appears secure at present. The continental population has stabilized and, in the absence of further human encroachment on the availability of feeding grounds and islands for nesting, appears capable of coexisting with man.

Efforts to establish white pelican colonies on artificial islands are under way at some of the lakes and reservoirs of eastern Colorado. Encouraging pelicans to nest at additional sites may result in increased numbers of these birds. More significantly, new nesting sites would provide supplemental breeding populations to buffer future human impacts on successful reproduction at any of the current pelican colonies. □

L T. Rhodes; Animals, Animals

Master Design of the Inca

by Craig Morris

Hundreds of preplanned towns and cities and an intricately engineered highway network held this society together

When the Spaniards interrupted the expansion of the Inca empire in 1532, it stretched some three thousand miles along western South America—from today's Colombian-Ecuadorian border south to central Chile. The Inca called their empire Tawantinsuyu, "the land of four parts." Few preindustrial states had ever grown to such size and the process must have presented immense difficulties. Within the empire lay some of the highest mountains and most difficult terrain in the world, but the Inca traveled it without benefit of either horse or wheel and conquered its diverse peoples, who spoke dozens of different languages.

Some of these conquests were of large, powerful, and wealthy kingdoms. The Chimú, the builders of Chan Chan on the coastal desert, are one example. The Lupaca, who lived with their vast herds of llama and alpaca on the altiplano near Lake Titicaca, are another. Even more remarkable was the rapidity with which these achievements were carried out. If reports by Europeans are correct, most of the empire had been formed in the century immediately preceding its discovery by Pizarro and his soldiers.

But strong armies and victories do not by themselves produce an empire. Conquest in faraway places depends upon reliable communications and supplies. An enduring state requires capable administration and organization—a link between ruler and

As a form of labor tax, the Inca state required its subjects to work in urban centers. These buildings at Huánuco Pampa once housed hundreds of workers who came to the city on a rotating basis.

Craig Morris

ruled. The vital element in the ability of the Inca to conquer and control was the extensive system of roads that bound the diverse parts of the empire together. The Spanish soldier-explorer Pedro Cieza de León well recognized the importance of this transportation network. In his *Chronicle of Peru*, which brought Europeans their first major description of the Inca only two decades after the conquest, his admiration of the roads led to some of his few moments of extravagance.

> In the time of the Incas there was a highway, built by man's hands and labor, which left this city [Quito, Ecuador] and extended all the way to Cuzco, and from there another began as large and magnificent as this which went to the province of Chile, which is more than 1,200 leagues from Quito. On these highways every three or four leagues there were very fine and well-built lodgings or palaces of the ruler, richly furnished. . . . In the memory of people I doubt there is record of another highway comparable to this, running through deep valleys and over high mountains, through piles of snow, quagmires, living rock, along turbulent rivers; in some places it ran smooth and paved . . . in others over sierras, cut through the rock, with walls skirting the rivers, and steps and rests through the snow; everywhere it was clean swept and kept free of rubbish, with lodgings, storehouses, temples to the sun, and posts along the way.

Although the Inca roads represented an impressive engineering feat, it was the centers built along them, which supported military operations, royal travel, and administrative functions, that lay at the heart of the Inca ability to rule such an immense land. The extent of the network was recorded in about 1615 by Guamán Poma de Ayala, an Andean of native ancestry. In a 1,200-page "letter" to the Spanish king, Poma wrote of his travels along the Inca road system and listed hundreds of towns and cities built by the empire. Some of these centers are still very evident, especially those in the altiplano, vast grassy plains that occur along much of the length of the Andes.

Preliminary investigations of the highway centers took place in 1964 and 1965 in a project directed by John V. Murra of Cornell University and the Institute of Andean Research. During this period, traveling on foot and horseback, we covered a sixty-mile section of the road in the Peruvian altiplano and examined several large sites accessible by Jeep. The evidence from that survey suggested that the centers along the road were of two types: small way stations about 25 miles apart and larger complexes at 75- to 125-mile intervals.

We investigated two centers, one of each type. Built during the reign of Topa Inca Yupanqui in the latter half of the fifteenth century and abandoned shortly after the Spaniards overthrew the Inca government, both centers are situated at an altitude of more than 12,000 feet on the main Inca highway from Cuzco to Quito. That the Inca built the greater part of the highway at this altitude may have been a calculated decision. Not only is the altiplano relatively flat, a characteristic that would have facilitated road building, but it is also the natural habitat of the llama, the beast of burden so important to the Inca. Another factor favoring the highway at this altitude concerned the transportation and storage of food. At 12,000 feet, nighttime temperatures are usually in the thirties, and food, such as potatoes, could have been preserved for long periods.

Although the Inca name for the larger site is uncertain, we called it Huánuco Pampa. It is located only about 75 miles across the Andean cordillera from Lima. But by the circuitous land road, the only current access, it is more than 300 miles distant. The small center, known as Tunsukancha, which I investigated with Delfin Zuniga, a Peruvian archeologist, is about 25 miles to the south of Huánuco Pampa.

The most prominent feature of Tunsukancha is a 200- by 400-yard plaza, surrounded on three sides by long narrow buildings that were probably used as lodgings for travelers. The fourth side of the plaza is partially closed off by a long wall. West of the plaza, a separate walled compound is divided into three sections containing ten small buildings and a bath. Excavations revealed evidence of cooking, such as ashes, bones, carbonized food remains, and shards from decorated vessels, in some of the buildings. The complexity of the center's architecture and the decoration of the cooking vessels suggest that the smaller buildings were part of a high-status residence area.

Only the section at the western extremity of the compound lacks evidence of cooking fires. Here, the Inca had lined a small pit with dressed stones to make a bath. Cieza and other sixteenth-century chroniclers record that special quarters were maintained for the Inca ruler at every center along the road. That this section had no shards or signs of fire, but contained a finely architected bath, the only one in the site, suggests that it may have been reserved for royalty. The two other subdivisions may have been used to house those responsible for administering the center and for the preparation of food not only for the residents but also for royalty and other travelers privileged to enter the compound.

The remains of twenty-four circular storehouses are located on the eastern periphery of the center, and a hundred or so crude structures—some circular and others rectangular—were situated between these storehouses and the main plaza. Excavations in one of these small buildings revealed ash and broken cooking pots. But almost all the ceramics here were undecorated, utilitarian wares, quite different in style from those found within the compound. The building seems to have served as a residence—perhaps of one of the people who helped maintain the way station. A small, inconspicuous structure (now badly destroyed) stood between the main plaza and the houses that probably lodged royalty. Its remains were ordinary except for its floor, which was strewn with thousands of potsherds. A small test pit

The Inca built most settlements and roads on the vast plains along much of the length of the Andes. The flat terrain made transportation easier and the high-altitude, cold temperatures helped preserve food.

Alan Ternes

resulted in almost as much broken pottery as earth. The extensive variety suggested that the shards originated from many parts of the Inca empire. Expanded excavations revealed many vessels, some nearly whole. Some contained charred maize and potatoes and had been placed next to a nearby altar, the food apparently serving as an offering.

The materials left behind by the Inca at Tunsukancha are very much what one would expect for a way station that had provided the needs of soldiers, officials, bureaucrats, and others traveling the royal roads. Royalty was sheltered and fed in comparatively elegant facilities, while common travelers lodged communally. The role of the small building with the altar is somewhat puzzling. It had been heavily used, yet no special effort had been expended on its construction and no particular prominence given to its location. Attention to the material and religious needs of travelers appears to have been the sole function of Tunsukancha. There is no evidence of manufacturing or agriculture, of permanent barracks or any large-scale administrative operation, or of a resident population beyond that needed for the service of travelers. It was simply one of the many establishments that made long-distance travel and communication feasible and efficient.

Huánuco Pampa, on the other hand, looks like a city, suggesting that at least some Inca centers in the provinces served as far more than communication, transportation, and supply stations. The great variety of activities in these urban developments formed the foundation for a complex and peculiarly Andean system of statecraft.

The city was founded no earlier than 1450, and perhaps as late as 1480, meaning that it had been occupied for no more than some eighty years before the Spaniards arrived in 1532. The sheer rapidity of its construction and peopling suggests large, perhaps forced, movements of people. Excavation results and artifacts suggest that between 10,000 and 15,000 people may have inhabited the city. The ruins of more than 3,000 buildings are spread over a high plain. On a nearby ridge, there were almost 500 additional buildings, in which the Inca could have stored just over one million bushels of potatoes, maize, and other foods transported from other parts of the empire. The entire city covered almost two square miles, making it at least ten times the size of Machu Picchu, the magnificent Inca city north of Cuzco.

Certainly Huánuco Pampa was one of the major Inca centers in the provinces, much of it showing evidence of elaborate planning. Excavations in the planned sections have revealed the foundations of cruder buildings, suggesting the evolutionary development and constant replanning of the city. Enough of these foundations, both crude and well masoned, have been preserved to give us an accurate plan of the city, the only Inca settlement where this has been possible. (It is also the only Inca center that has received intensive archeological investigation.)

In spite of enormous differences in size and in function, Huánuco Pampa and Tunsukancha had two important common purposes. First, they were both on the Inca road and therefore part of the same over-all network. Second, the architecture and much of the pottery in both centers show deliberate imitations of the Inca capital at Cuzco. Except for the vessels around the altar, most of which were probably left by travelers, the materials, techniques, and styles of the pottery at Tunsukancha and Huánuco Pampa are identical. The contrast with the pottery of local villages is obvious, leaving no doubt that the way stations and urban centers on the road were planned by Inca administrators from Cuzco. So complete is the exclusion of local pottery styles in the centers along the highway that it appears an imperial design imitating that of Cuzco was always used, despite the fact that each local non-Inca village had its own style.

Alan Ternes

This bath, constructed in the midst of Huánuco Pampa's finest buildings, was probably used by Inca royalty. Water flowed into it through stone pipes from a nearby spring.

One possible reason for the marked distinctions in pottery and architectural styles is that the centers were built and populated almost entirely by people transplanted from other areas. Under the Inca system, most labor was done by peasants who worked on a temporary and rotating basis. This form of labor, called *mit'a*, was essentially a labor tax. Some of the inhabitants of Huánuco Pampa were probably brought from Cuzco; others from local villages. Sometimes this involved moving entire communities, essentially as colonies, from one part of the empire to another. Most of the people in Huánuco Pampa thus remained only as long as their state duties dictated, the population constantly shifting as one group of laborers replaced another.

In 1965 I studied the storage complex at Huánuco Pampa, excavating almost 120 buildings. From 1971 through 1974 I directed an archeological team that conducted topographic work for a detailed plan of the city, making more than a thousand excavations and recovering at least five tons of pottery, animal bone, and other archeological material. The analysis of this material is not yet complete, but a preliminary map has been drawn and a tentative picture of Huánuco Pampa is emerging.

The city was planned in four areas around a large central plaza. In the center of the plaza, a 200- by 250-foot platform of dressed stone stands almost 20 feet high. The eastern section is the most rigorously planned and architecturally spectacular. To one side, a high terrace overlooks a small artificial pool enclosed by a long trapezoidal wall. To the west of the terrace, a group of six dressed-stone buildings stands near a stone-lined bath, another artificial pool, and three less finely built structures. Unfortunately, the Spaniards altered the area to such an extent that we cannot tell how the Inca used it. The bath and the fine quality of the construction, however, lead me to believe that this area may have been reserved for the Inca ruler himself—a more elaborate version of the complex discovered at Tunsukancha.

A series of thirteen long halls arranged around two spacious plazas are contiguous with the bath and pools. The plazas are connected by

Alan Ternes

gateways of dressed stone and are part of the painstaking planning of the entire sector. We had expected that these large structures were probably devoted to state administration. But when excavations directed by Pat H. Stein, one of the members of our team, produced an abundance of food remains and literally tons of culinary pottery, we had to search for a different hypothesis. The entire area appears to have served as an enormous kitchen complex where *chicha*—the native maize beer—and a wide variety of foods were prepared and served.

The location of these cooking and dining areas in the city's most elaborate buildings near the royal quarters suggests that eating and drinking was a vital element in the Inca provincial administrative system. The relationship between the Inca rulers and the populace was to a great extent ceremonial, involving feasting and festivals. Ritual was essential to administration of this system. While no records exist of such affairs taking place at Huánuco Pampa, Cieza wrote about one such ritual held in Cuzco, and his description may typify such events in other centers.

> Thus they say that it was the custom of the Incas of Cuzco to have all the statues and figures of the idols in the *huacas,* which were the temples where they worshipped, brought into that city each year. They were transported with great veneration by the priests . . . and guardians. When they entered the city, they were received with great feasts and processions and lodged in places set aside and appointed for that purpose. And people having assembled from all parts of the city and even from most of the provinces, men and women, the reigning monarch, accompanied by all the Incas and . . . courtiers, and important men of the city, provided great festivals and *taquis* [drinking bouts].
>
> And so, making the people joyful and giving their solemn banquets and drinking feasts, great *taquis,* and other celebrations such as they use, completely different from ours, in which the Incas show their splendor, and all the feasting is at their expense, where there were vessels of silver and gold, and goblets and other things. . . .

This kind of pomp was probably as political as it was religious in nature, serving to solidify and impress the many laborers necessary to support the Inca system. There is evidence, however, that other means were employed to supervise some workers. On the northern side of the city's main plaza, the remains of a series of fifty buildings are neatly arranged within a walled enclosure. In these ruins we discovered more than 300 spindle whorls and numerous bone awls and tools used for manipulating threads in a loom. A study of the enclosing wall disclosed that this area, apparently the city's cloth-making center, had only one entrance. Anyone entering the compound had to pass through the opening in the outer wall, cross a courtyard, and pass through a small building. No other sector in the entire city, except for the area probably used to house the ruler himself, had such thorough control of access and egress.

Excavations in and around the buildings in the compound uncovered several of the copper pins used by Andean women to fasten the mantles they wore about their shoulders. The pins and the tight security of the area, plus the fact that spinning in the Andes was—and still is—usually done by women led me to believe that we had found a residence and work compound used by the *akllakuna*—the "chosen women" or "virgins of the sun." Early Spanish observers usually emphasized the religious role of these women, but also reported that they made cloth and *chicha.* The finding of huge amounts of pottery from large vessels suggests that brewing may also have been an activity in the compound.

If our reconstruction of the nature of the enclosed group of buildings is correct, we have evidence of an unusual way of organizing production. The *akllakuna* served the state under tight security, passing much of their time isolated in the compound—spinning, weaving, and perhaps making *chicha.*

The kinds of goods produced in Huánuco Pampa are just as noteworthy as the manner in which their production appears to have been organized. Several years ago John Murra spelled out the extraordinary significance of cloth in the Andes, noting its pervasive use in rituals and ceremonies. It was involved not only in an individual's *rite de passage* but was also of considerable political importance, since the incorporation of a newly subdued people into the empire was usually accompanied by gifts of cloth. Cloth was also issued to soldiers, making it militarily important.

Only a small part of Huánuco Pampa was constructed of stones cut to fit tightly together. The Inca used such masonry techniques in building their most important structures.

Since cloth was of such crucial political as well as economic value, it is not surprising that the state would take measures to assure itself of a substantial and growing supply. The more cloth it had, the more effectively it could raise and control armies and other workers, and the more successfully it could consolidate and control conquered areas. The growth of the state depended in part on its ability to increase and control the supply of textiles. The establishment of a production facility under direct state control was probably a very effective means of insuring the supply of such an important commodity. Such centers as Huánuco Pampa provided an ideal setting for the controlled, standardized production of textiles in the styles that symbolized the Inca and their state.

Some archeologists and historians have characterized the Inca as a purely rural people because evidence of their cities is scanty in comparison with other civilizations. Part of this attitude is a result of the destruction, at the hands of the Spaniards, of many of the Inca's larger urban complexes.

The remains of almost 500 round buildings where maize and potatoes were stored follow the contours of the hills near Huánuco Pampa.

Alan Ternes

Those that survived, like Huánuco Pampa, did so because of their remoteness, a factor that has also contributed to the lack of archeological knowledge about such sites.

Some reservations about referring to the Inca as an "urban" civilization are warranted. As an example of an urban area, Huánuco Pampa had certain peculiarities. One was its fragility. Its maintenance was so dependent on the Inca state that when the governmental organization was thrown into disarray by the murder of Atahualpa by the Spaniards, the center was quickly depopulated.

The critical point is that the focus of Inca urbanism, if we are to call it that, was not the individual city. Instead it was a meticulously planned network, which included small way stations, large administrative centers, and other kinds of installations not as yet identified. Each center performed certain functions in the interest of the over-all success of the empire. The emphasis was not on an individual region made up of a city and its supporting hinterlands, but rather on an entire realm tied together into a single political and economic entity. Thousands of miles of roads and hundreds of settlements, large and small, were built to accomplish the task. In several of the sites we investigated, many buildings were unfinished, and some of the completed buildings at Huánuco Pampa had not yet been used. The system was still growing and probably did not yet function as smoothly as the Inca rulers wished. But however incomplete and flawed it may have been, it demonstrated a master strategy of empire building unparalleled in the ancient New World, and matched in the Old World only by Rome and perhaps China. How fascinating it would be to know what would have happened to this empire if the Spaniards had stayed home in 1532. □

This twenty-foot-high platform dominates a vast plaza in the center of Huánuco Pampa. It was probably used as a reviewing stand by Inca administrators during ceremonies.

Craig Morris

Celestial Events

by Thomas D. Nicholson

Sun and Moon The sun moves into Sagittarius (the constellation, not the sign) on December 17, reaching the winter solstice at 12:36 P.M., EST, on December 21. It will then be at its most southerly point in the sky above earth, bringing the shortest day and the longest night of the year to the Northern Hemisphere (but not the earliest sunset and the latest sunrise). The sun remains in Sagittarius past mid-January, but by then it will have moved perceptibly northward and sunsets will occur noticeably later (although the time of sunrise will not have changed).

The moon will be showing up as a pretty crescent in the southwest along about Christmas Eve. From the 23rd until the 25th of December, it will be near Venus (by then a very distinctive evening star), and together, the two will make a memorable celestial decoration appropriate for the holiday season. The moon will remain a prominent evening object through the first week of January, becoming a morning object thereafter. New moon is on December 20, first-quarter on December 28, full moon on January 5, last-quarter on January 12.

Stars and Planets The evening Star Map includes Jupiter (near the border between Aries and Taurus) and Saturn (between Leo and Cancer). It does not show Venus, our most prominent evening star, because Venus sets too early to be included. At dusk, you will see Venus brilliant and low in the southwest; Jupiter well up in the east. Saturn will rise in the east shortly after dark. At daybreak, Jupiter will be low in the west; Saturn high up in the south.

Although the winter stars of the Northern Hemisphere are among the brightest and most beautiful of the year, those living in the north miss the advantages that accrue to inhabitants of the Southern Hemisphere at this time of year. Far below the equator, where residents still enjoy our bright northern stars of December and January, they also have the southern branch of the Milky Way, with the Southern Cross and its surrounding region, high in the sky. And on their long winter nights, which come in July and August, they also have the magnificent region of the sky near the winter solstice high above them. We see it only low in the south on our short summer nights.

December 16: Before dawn, you will see the crescent moon approach Spica. It covers the star (an occultation) to the north.

December 19: Moon at perigee, nearest to the earth.

December 20: Mercury is at greatest easterly elongation, but not favorably placed as an evening star.

December 21: Winter begins in the Northern Hemisphere.

December 22: The weak and dim Ursid meteors reach maximum.

December 23–25: Look for the moon and Venus each night.

December 31: The moon is at apogee, farthest from the earth, and passes very near Jupiter this evening, covering it.

January 3: Earth is at perihelion, nearest to the sun.

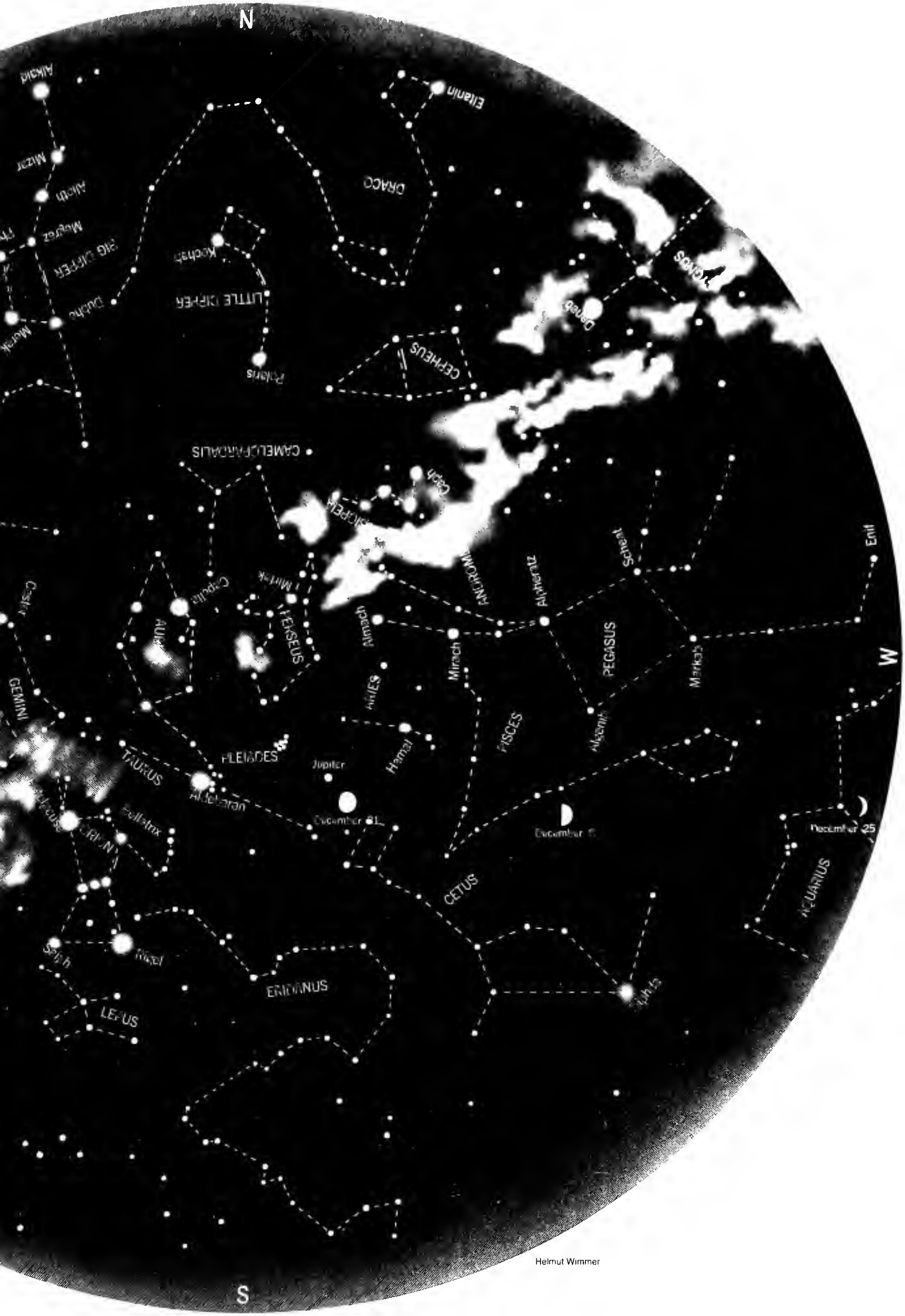
January 4: Latest sunrise occurs.

January 6: Mercury is in inferior conjunction, passing between the earth and the sun, becoming a morning star.

January 7: Look for Saturn near the moon.

January 15: Jupiter is stationary with respect to the stars. It now begins to move east (toward Taurus).

★ Hold the Star Map so the compass direction you face is at the bottom; then match the stars in the lower half of the map with those in the sky near the horizon. The map is for 11:15 P.M. on December 1; 10:20 P.M. on December 15; 9:15 P.M. on December 31; and 8:15 P.M. on January 15; but it can be used for an hour before and after those times.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Scheat
PEGASUS
Markab
Algenib
Enif
ARIES
Hamal
PISCES
PLEIADES
Jupiter
TAURUS
Aldebaran
December 31
December 8
December 25
AQUARIUS
CETUS
Bellatrix
Rigel
Saiph
LEPUS
ERIDANUS
Helmut Wimmer

Landing of British troops on Long Island, August 1776

Culver Pictures

The Search for the *Culloden*

by Henry W. Moeller and Steven A. Giordano

Marine archeological excavations often become frustrating battles against artifact-seeking scavengers

On a cold January day in 1781, the *Culloden*, a 74-gun British ship of the line, set out from Gardiners Island off New York's Long Island to intercept French vessels that were about to sail from Newport, Rhode Island. A good part of the British fleet was wintering off Gardiners Island that year to prevent colonists from seizing eastern Long Island from the British, who had held it since General Howe landed there in August 1776.

Soon after being dispatched, the *Culloden* and two companion ships, the *Bedford* and the *America* were lashed by a northeaster. Aborting the chase of the French vessels, the three ships headed for the open sea to weather out the gale winds and driving snow. The *America* successfully cleared Montauk Point at the eastern end of Long Island and was swept south to the North Carolina capes where she rode out the storm.

The *Culloden* and the *Bedford* plunged eastward out to open sea, but after midnight the weather thickened and the two ships became separated. Both were driven toward the north shore of Long Island. When the *Bedford* was almost aground her crew managed to set an anchor north of Montauk Point and in a final effort to save the ship, cut away her masts. Although defenseless, the *Bedford* was able to weather the fury of the storm while anchored just off the rocky beach.

The *Culloden* fared worse. Like the *Bedford,* she struggled as tons of foaming water crashed upon her decks and gale winds blew her sails to shreds. At court-martial proceedings held two months later, Ralph Grey, the ship's fourth lieutenant, testified that just before daybreak on the day the ship went aground, "some person gave an alarm of land and breakers upon our lee bow. I immediately ran to leeward and saw the land on the lee beam . . . at this moment I heard Captain Balfour give orders to cut away the anchors and I immediately repeated the orders, but before the order could be complied with, the ship struck."

Captain George Balfour reported during the inquiry that soon after she went aground, the ship's rudder broke in two and was lost. As hail and snow continued to fall, small boats were launched to make soundings around the ship. According to Grey, "At eight o'clock the ship payed off with her head to the northwest, and she then came broadside to and there struck fast." As the tide came in, the crew attempted to free the ship from the beach, fully expecting that the copper sheets sheathing her hull had protected her from serious damage. To lighten the load, all twenty-eight of the ship's massive 32-pounders were probably thrown overboard. But a giant boulder prevented the ship from paying off and may have seriously damaged it. Six to nine feet of water filled the ship's holds. The captain instructed the crew to get the ship's stores and provisions ashore, lest they fall into enemy hands.

For three weeks—marked by squalls, gales, and snow—the crew, many of whom were sick, transferred most of the stores as well as twenty-eight 18-pound cannon and eighteen 9-pound cannon to three ships, including the dismasted *Bedford*, which was then being refitted for sea duty once again. Her rigging was also transferred aboard the *Bedford.*

The youthful *Culloden,* six years in construction and requiring at least 60 acres of oak forest, was then burned to the waterline to prevent the colonists from salvaging her. She had been launched at His Majesty's shipyard in Deptford, England, on May 18, 1776, less than five years before her career ended. One of the nine largest ships lost by the British in the American Revolution, the *Culloden* was a third-rate man-of-war, with a length of 170 feet and breadth of 47 feet. She had three decks and carried a complement of 650 officers and seamen. The fire destroyed her down to the level of the third deck, leaving intact fifteen feet of hull below the waterline.

The *Culloden* was just one of more than 500 ships that have met their end off Long Island's Montauk Point in the past 200 years. Long Island juts 120 miles into the Atlantic and much of New York's ship traffic to or from the north and east passes close to Montauk Point, the easternmost end of the island. Here, winds and ocean swells pound the coast, and the three shoals lying just off Montauk Point have accounted for the loss of many ships, even though a lighthouse has perched there since the end of the eighteenth century.

Despite British efforts to destroy

the wreck, historical documents indicate that the *Culloden* did not sink into immediate obscurity. After the winter of 1781 had ended and the British had left Long Island, Joseph Woodbridge of Groton, Connecticut, salvaged sixteen of the *Culloden*'s 32-pound cannons and offered them for sale to George Washington and the Continental army. Although Washington was interested in the offer, the purchase was never made and the cannons' eventual disposition is not known.

Other attempts were made to salvage the *Culloden*. In 1796, the caretaker of Gardiners Island apparently led people from eastern Long Island and Connecticut in salvage operations that removed the ship's iron fittings, copper bolts and sheathing, and remaining rigging. And in 1815 a man named Jeffers lowered a diving bell from his sloop and recovered one 32-pound cannon from the wreck site.

After the early nineteenth century, however, the precise whereabouts of the *Culloden* were lost. Over the decades, sand had gradually accumulated over her remains and salvage crews, having removed the ship's commercially valuable parts, had no interest in maintaining her location. One hint, however, remained. For many years a piece of ship's timber had protruded above the surface of the water off Culloden Point, an elbow of land near Montauk Point where the ship had gone aground. But because four other ships had also gone aground off this point, historians were not certain whether the timber was a part of one of these ships or of the *Culloden*.

During a storm in the 1950s, the timber worked itself free and washed ashore. Some 60 feet long, it was curved in the shape of a ship's prow, which led historians to believe that the piece was originally part of an apron—reinforcing timbers ordinarily attached to the inside of the stem. Before archeologists could examine the piece carefully, however, picnickers used it as fuel for a campfire. Whether the apron was a part of the *Culloden* or of some other ship will never be known.

Not until 1971 did more clues turn up. In the early summer of that year, while scuba diving in ten to fifteen feet of water off Culloden Point, we came upon pieces of wreckage lying in the sand on the ocean bottom. Winter storms had apparently scoured away a level of sand in the shallow water, revealing the ancient timbers that had previously been buried. Curious about the timbers, we asked an associate at the New York Ocean Science Laboratory (NYOSL), where we are doing research in marine biology, and two other divers to accompany us in a further exploration of the site.

That dive far exceeded our expectations. Digging in the sand next to the large beams, we uncovered a brass gudgeon (a socket attached to a ship's sternpost to receive the rudder) with, ironically, the *Culloden*'s name misspelled on it; one *l* was missing. The name of the ship misspelled or not, this find virtually confirmed the location of the *Culloden*. We also found an iron ballast bar, small pieces of copper sheathing, and a few nails. Not long afterward, we also discovered part of the split rudder that Captain Balfour had mentioned in 1781. These artifacts are now in the East Hampton Marine Museum.

By law, the excavation of any archeological site in New York State is illegal unless permission is granted through the state's Department of Education. Until this permission was forthcoming, we were forced to desist from further exploratory excavation. Other divers, however, ignored the restriction and proceeded to excavate without our knowledge. A major finding was a 9½-foot-long iron cannon. Probably cast in Scotland in the 1760s, it is stamped with a lavishly scripted "GR," for "Georgius Rex II." Another stamp on the cannon is shaped like a broad V, signifying that it belonged to the crown.

One of the divers took the cannon to his backyard where it drew considerable attention from both the press and small children. Word of the discovery quickly spread, and in the months that followed, the wreck site became a haven for scores of weekend scuba divers. They quickly stripped all accessible wreckage and walked away with metal artifacts and 50-foot-long pieces of timber. Fortunately, the state took title and ownership of the cannon, and in cooperation with the town of East Hampton, scientists at NYOSL are now taking steps to preserve it. Once the preservation work is completed, the cannon will be displayed so that any number of people can study and enjoy it.

The state has granted to NYOSL permission to excavate the site, and local and state police are attempting, somewhat futilely, to bar unauthorized persons from the site. Nevertheless, numerous pieces of the *Culloden* have already been lost, probably forever. If the remainder of the hull is ever excavated and restored, these missing parts will make the archeologists' job even more difficult than it already is.

The *Culloden* is just one example of the potential fate of most underwater wrecks. Almost 98 percent of these ships in the Western Hemisphere lie in water less than thirty feet deep, making many of them easily accessible to a scuba-diving population that in 1975 had increased by 25 percent over the previous five years and totaled between 500,000 and 750,000 people. Not all of these divers, of course, seek wreck sites, but when a diver does come upon one, his or her excitement at the discovery often makes it difficult to refrain from taking artifacts.

Long Island wrecks are now beginning to disappear from the ocean, only to turn up in bits and pieces on front lawns, patios, and doorsteps. Not long ago scuba divers brought up a mast from the *Franklin*, a sidewheel steamer bound for New York from France in 1854 when it struck a sandbar six hundred feet off the town beach of Center Moriches, Long Island. As soon as they had maneuvered the mast to shore, the divers stripped the hardware from it. Later the bare mast was carted off to the dump after townspeople complained that it interfered with activities at the town's boat ramp.

An even more drastic case of plundering concerned the *Black Warrior*, a sail-rigged steam packet that sank in 1852 in thirty feet of water off Rockaway Beach. Her identity remained a mystery until 1961, when divers found pieces of silverware bearing the imprint "Black Warrior—officers" scattered off the beach. Shortly after this discovery, divers stripped the wreck of all re-

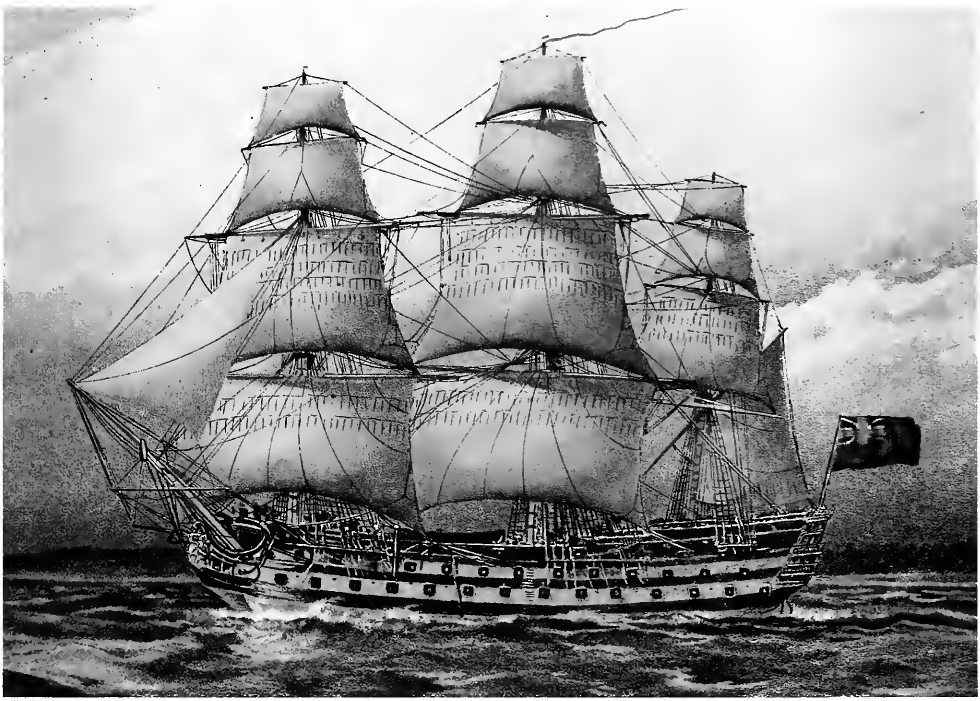
movable metal. In one instance, they recovered the intact copper smokestack and when they had it on shore, backed a dump truck over it to flatten it, then sold it for scrap to a local junk dealer.

The *Franklin* and the *Black Warrior* are just two of the hundreds of wrecks that lie on the ocean bottom off Long Island. Scuba divers are bound to discover others, and their fate, once located, is extremely uncertain. Some of these wrecks are of enormous archeological value. The *Savannah*, for example, lies in the water off Brookhaven where she sank in 1821. Two years earlier she had crossed the Atlantic under steam, the first ship to have done so. An understanding of her construction would be of great archeological and historical interest, especially since none of her original plans were preserved.

Another ship that foundered was the *Finian Ram, Jr.*, a steel submarine designed by John P. Holland, one of this country's two pioneer submarine architects. This submarine, one of a series he constructed in an effort to perfect the use of water ballast and horizontal rudders for diving, was lost off Long Island in 1883 while under tow.

What will happen to these and other wrecks when and if they are discovered? Federal and New York State laws to prevent plundering of archeological sites are explicit but hardly enforceable. Even if discovered wrecks are reported and investigated by marine archeologists, efforts to recover and preserve artifacts are slow in coming. The problem is ordinarily a lack of finances. Even those public agencies or private organizations that could provide financing are often reluctant to do so because of the typically slow progress of a marine excavation. In marine archeology, instant gratification—an impetus to sponsors to continue funding—does not come often. An exception to the usual lack of financing, of course, is the discovery of a ship that might bear treasure. In such a case, the excavation might not only pay for itself but could also bring income into state coffers through taxation of the treasure. States such as Florida, whose waters hold gold-bearing wrecks, have been far quicker to respond to archeological projects than states with sites that have no monetary value, such as the maritime cemetery off Montauk. But even treasure hunters admit that the sea floor is not strewn with treasure, only visions of it. Florida treasure hunters covered 120,000 square miles of sea bottom before locating the Spanish treasure ship *Atocha*.

For the most part, the treasures consist, not of gold and silver, but of rusted and misshapen artifacts whose major value is the substance and detail of history, a value which far surpasses monetary considerations. Our history is sparsely dotted with tangible examples of the past. Now that the technology exists to recover and preserve artifacts, we should not permit the remaining details of marine history to be consigned to backyards and doorsteps, where they will be almost as hidden from the public as they were during all the years they were on the ocean bottom. □



An eighteenth-century British battleship similar to the Culloden

Culver Pictures

Golden Trout in Trouble

by Margaret F. Gold and John R. Gold

A dubious ancestry and an unhelpful boost from fishermen have cast a shadow over a most beautiful fish

Fed by melting snows, the headwaters of California's Kern River form in the shadow of the towering Sierras. Many streams tributary to the Kern also arise from a snow birth. Dropping rapidly away from the cradling heights of the Sierra Crest and Great Western Divide, they flow down wooded slopes and through meadows, uniting, growing, and finally joining the southerly progress of the Kern. In these streams lives *Salmo aguabonita,* the golden trout of the High Sierra—possibly the most beautiful of all the many forms of western North American trout.

Originally, goldens were found only in the upper Kern River drainage. Their narrowly restricted distribution was due, in part, to a cul-de-sac formed by mountain barriers and to an adaptive response to cold and swiftly flowing streams. Through the intensive stocking efforts of numerous people, golden trout distribution now includes many Sierran waters. Nevertheless, dating from the advent of the first naturalist on the Kern River plateau, concern has been expressed—with good reason—for the future of these magnificent fish.

Today the golden trout is a threatened species despite a long history of management intervention. Remedies for this near-tragedy will have to be based partly on an understanding of the past mistakes that contributed to their present status, but equally important will be historical and biological knowledge of the golden trout. Although scientific interest in these fish dates from the late 1800s, little is known about their evolution, behavior, and habitat.

The flow pattern of streams draining into the upper Kern River resembles that of a pinnately veined leaf. Several large veins, specifically the Little Kern River to the west and Golden Trout Creek and the South Fork of the Kern River to the east, radiate from the midrib—the Kern. These major tributaries are intersected many times by smaller streams arising from melting snow, rain, and the seepage of underground springs.

Pure populations of endemic golden trout are found only in waters located in the higher portions of the Little Kern and the South Fork regions. Naturalists have long distinguished between these two regions of the upper Kern River drainage.

Golden trout, Rocky Basin Lake, Tulare County, California

Briefly, the South Fork of the Kern River and the Golden Trout Creek drainages lie on a plateau known generally as the "South Fork"; the Little Kern River drainage is essentially a basin and is called the "Little Kern." The headwaters of each region originate at altitudes of more than 11,000 feet and are separated, in part, by the Great Western Divide.

Streams in the upper, plateau portion of the South Fork region are characterized by a gentle gradient as they fall toward the Kern River. Much of the plateau consists of meadows surrounded by sparse pine forests. Like steps on a gigantic stairway, each large meadow gives way, often with a short, steep descent through forest, to yet another meadow. Sagebrush is encroaching on many of the meadows, largely as a result of overgrazing by domestic stock and the subsequent erosion and lowering of the water table. The soil in this region is primarily coarse, decomposed granite, and vegetation along the stream banks is scanty. Although geographically a part of the South Fork drainage region, the area surrounding Golden Trout Creek is, in contrast, distinguished by denser riparian cover and evidence of volcanic activity. The stream substrates of many South Fork tributaries are composed of granitic sands and dull-red gravel, while the substrate of Golden Trout Creek contains light lemon-yellow tufa, a by-product of vulcanism.

The upper portion of the Little Kern basin is steep and thickly forested by pine and fir. The streams that race down these steep slopes are shaded by dense growths of young willows, alders, and cottonwoods. At higher elevations in the basin, metamorphic rocks overlie the granitic batholith and multicolored surfaces are in evidence along the stream beds. There may be some connection between the coloration of these substrates—the red, orange, and lemon-yellow hues found in section of both upper Kern River drainage regions—and the brilliant colors of golden trout.

Evidence of extensive glaciation persists in the higher reaches of both regions, where the granite peaks are scoured and polished. The retreating glaciers left hanging troughs with steep stream gradients, or waterfalls, which are impassable barriers to invading trout. Until they were artificially stocked, the lakes and streams above these barriers were devoid of fish life.

The streams in both the Little Kern and South Fork regions exhibit char-

E. Philip Pister

acteristics similar to that of other Sierran streams with granitic substrates—notably a pH above 8 and a lack of chemical nutrients. Generally, streams with more than a quarter of a cubic foot per second flow (August-September minimum) are suitable for golden trout. The amount of water flowing in the upper Kern River drainage streams is determined by precipitation, mostly in the form of snow, ranging between 30 and 40 inches annually.

Golden trout do not tolerate warm water temperatures. They are not found in water exceeding 75°F, suggesting that their critical level of temperature tolerance is approximately 70° to 74°. Water temperatures optimal to golden trout range between 40° and 60°. During the dry summer and fall months when ambient temperatures occasionally surpass 80°, cool snow water seeps from underground springs and feeds into the streams. Nights, even in the summer, are cold. In the winter, surface temperatures often drop low enough for ice to form on the streams.

Golden trout have adapted well to this high mountain habitat. Averaging about five to six inches in body length, they are small and sleek, fully able to swim the shallow, cold streams and easily jump small, natural barriers. Goldens seem to be opportunistic feeders, dining on terrestrial insects in the summer and early fall. In the winter and early spring, they probably subsist on a limited supply of water fauna, such as caddis fly and midge fly larvae and small crustaceans.

Golden Trout Creek, Tulare County, California E. Philip Pister

Like most trout, goldens spend much of their time in pools. There is little evidence of dispersal to other stream sections as a direct result of the aggressive behavior of golden trout within their home territory. Some movement away from the home pool may occur during the winter or during the spawning season, but this could be related to population density and food supply. When one pool is filled to its carrying capacity, excess trout must find adequate food elsewhere. Generally, it is the juvenile goldens that emigrate in search of other suitable living space.

Very little is known about the spawning behavior of stream-dwelling golden trout, as they generally spawn before the heavy snows have diminished sufficiently to allow biologists access to the upper Kern River drainage. Nevertheless, extensive information on spawning has been gathered at the inlet and outlet streams of the Cottonwood Lakes by fisheries biologists collecting fertilized eggs for artificial propagation in hatcheries. Although goldens were artificially introduced to these lakes, their spawning habits there probably differ little from those of the stream-dwelling forms. In both instances, swiftly flowing, cold streams with gravel beds are necessary to the successful spawning and hatching of golden trout.

Spawning among lake-dwelling goldens usually begins at the end of their third year. The coloration of the males intensifies and an enlargement of the upper jaw, or maxillary, becomes noticeable.

The female constructs a redd—a slight depression in the gravel of the stream floor—and deposits her eggs as the male extrudes milt. The number of eggs deposited is dependent on the body size of the female. Females of 8.5 inches produce about 300 eggs, while 12-inch females produce about 700. The redd is then covered with gravel. Swift, cold water (between 45° and 55°F) aerates the eggs. Within this temperature range, the water contains enough dissolved oxygen for the developing embryos, but

it is not so cold as to slow down their metabolism.

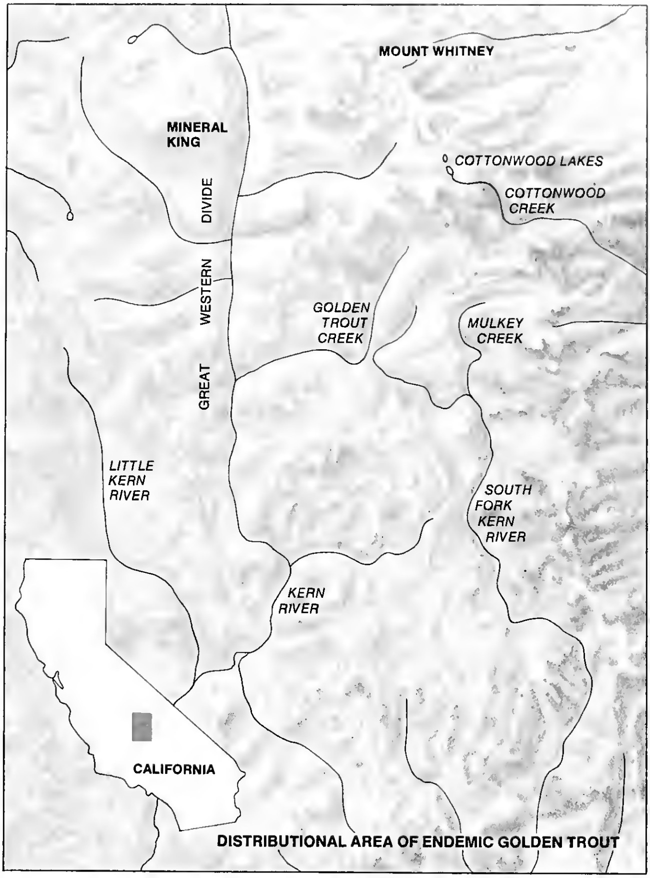
By the end of twelve days, the developing eye shows as a black dot through the egg membrane, and the eggs usually hatch in twenty days. The small fry lie helpless in the gravel, gradually absorbing nourishment from a yolk sac attached to their abdomens. Within eighteen days after hatching, the yolk is absorbed and the fingerlings, now almost one inch in length, emerge swimming freely from the gravel.

Growth during the first summer is rapid while the fingerlings dine voraciously on microscopic organisms. Thereafter, the growth of a fingerling into an adult is dependent on the availability of larger aquatic and terrestrial organisms and, to a lesser extent, on water temperature. Most streams in the upper Kern River drainage exhibit a low level of primary productivity owing to their high pH and lack of nutrients. Moreover, insects and larvae are not abundant. Golden trout in the upper Kern drainage grow slowly and remain small, never attaining the body size of transplanted goldens living in waters with more favorable conditions.

It is unfortunate that golden trout have not been studied, behaviorally and ecologically, to the same extent as many other species. But this is often the case when man's attention is focused on the pursuit of his own pleasure—in this instance, the sport of capturing a rare and beautiful fish. Until recently, much of the interest in golden trout was expressed by puzzling over their taxonomic status and by directing their preservation and propagation as a desirable game fish. While sometimes beneficial, this telescopic altruism has confused scientific understanding of golden trout and has resulted in many of the unfavorable conditions that now threaten them.

Historical and zoogeographical relationships among the original, isolated populations of golden trout in the upper Kern River drainage are confounded by the so-called coffee pot transplants of the late 1800s and early 1900s. Cattlemen carrying supplies and equipment to their summer camps in the high meadows of the Kern River plateau would pause to catch golden trout for the purpose of releasing them in nearby, presumably barren streams. It is not known whether all of these streams were, in fact, barren of other trout nor are the extent and location of these transplants known. However, golden trout travel well, and one can assume that many of these fish survived a variety of conveyances, such as coffee pots and frypans, to populate streams near the stockmen's campsites.

In papers written during the early twentieth century, B.W. Evermann of the U.S. Bureau of Fisheries, substantiated numerous transplants of golden trout. Perhaps the most significant transplant—the source of the only brood stock used in artificial



Two subspecies, or races, of golden trout are now recognized by ichthyologists: Salmo aguabonita aguabonita *and* S. aguabonita whitei. *Perhaps only one pure population of* S.a. whitei *survives in an isolated location in the Little Kern River drainage, where it has not been exposed to rainbow trout. Pure populations of* S.a. aguabonita, *endemic to the South Fork of the Kern River and Golden Trout Creek, are threatened by beavers and livestock grazing (habitat destruction) and by introduced brown trout (food competition). An uncontaminated population of* S.a. aguabonita, *transplanted from Mulkey Creek in 1876, lives in a glacial lake near Cottonwood Creek.*

propagation of golden trout—was made by the Stevens brothers, who in 1876 captured golden trout from Mulkey Creek, a tributary of the South Fork of the Kern River, and transported them to a site in Cottonwood Creek adjacent to their sawmill. Soon these entrepreneurs were joined by anglers and sportsmen's clubs in transplanting golden trout.

In 1909 the California Fish and Game Commission began to take an active role in the transplantation of golden trout to barren waters. Their efforts, along with those of private individuals and groups, were praised in several articles and a popular book. Fear ran high that these remarkably beautiful fish would be exterminated in their limited and fragile habitat. Expanding their distribution seemed desirable and was encouraged. It was only in later years, as pressure to stock grew and rainbow trout were introduced into some original golden trout streams in the Little Kern drainage, that this somewhat indiscriminate policy was seen to be working against its stated aims.

Taxonomic splitting—the giving of separate species names to each new discovery—has also confused our understanding of the historical relationships among golden trout. In 1875, biologist H. W. Henshaw caught a trout of exquisite beauty from the South Fork of the Kern River. He identified it as *Salmo irideus,* an early name of the rainbow trout; his 1878 report on this fish is the first scientific record of what we now call the golden trout. When David Starr Jordan, then president of Stanford University, in 1892 received three specimens of a similar fish from Cottonwood Creek in the nearby Owens River drainage (stock presumably derived from the Stevens brothers' transplant), he christened them *S. mykiss aguabonita.* Following the nomenclature of the time, this indicated that the golden trout belonged to the cutthroat series. However, within a few years, other works of Jordan placed it with the rainbows.

At the request of President Theodore Roosevelt, Evermann led a group of scientists into the upper Kern River drainage. Based on observations made in the summer of 1904, Evermann described three species of golden trout that he considered part of the rainbow trout series: Jordan's *S. aguabonita,* native to the South Fork of the Kern River drainage; *S. roosevelti,* of Volcano (now Golden

Trout) Creek, named by Evermann in honor of the president and called the "real golden trout"; and *S. whitei* of the Little Kern River drainage.

Throughout this taxonomic history, there was no question among scientists that golden trout belong to the genus *Salmo*, which includes, among others, the rainbow and cutthroat trout. However, relationships among the goldens at a species level still are confused by the variety of designations given them by early scientists. Confusion also arises when one considers the frequently obscure and overlapping phenotypic criteria, such as coloration and spotting, which were described in the effort to distinguish different species. For instance, Evermann said of *S. roosevelti*, "[it] is the most beautiful of all the trouts . . . the delicate golden olive of the head, back and upper part of the side, the clear golden yellow along and below the lateral line, and the marvelously rich cadmium of the underparts fully entitle this species to be known above all others as *the* golden trout." He contrasted this species with *S. aguabonita*, the golden trout of the South Fork of the Kern River and its tributaries. Although the two "species" are lightly spotted above the lateral line, Evermann reasoned that geographical isolation, in conjunction with differences in color and spotting intensity, was sufficient to warrant calling them different species. In reality, these differences are so slight that many trained observers have experienced difficulty in distinguishing between populations of golden trout and even between certain populations of rainbows and goldens.

In 1935, biologist Brian Curtis eliminated much of this confusion. He noted that tremendous variation in color and spotting existed among golden trout in the five Cottonwood Lakes. Had Curtis not known that the originally barren Cottonwood Lakes were stocked with golden trout from Cottonwood Creek in 1891, and that the Cottonwood Creek trout were derived from the original Stevens brothers' transplant of goldens from Mulkey Creek, he would have been convinced that he was observing two different species of golden trout, *roosevelti* and *aguabonita*. He concluded that the two species were one and the same and that any differences between the two types could be attributed to the wide range of color variation found in golden trout.

Today, most ichthyologists recog-

nize only one species of golden trout, *S. aguabonita*, consisting of two subspecies, or races: *S.a. aguabonita*, endemic to the South Fork of the Kern River and Golden Trout Creek; and *S.a. whitei*, native to the Little Kern River drainage.

Nevertheless, despite the years devoted to positive statements regarding the golden trout's position in taxonomic classifications, their origins and relationships to other members of the genus *Salmo* remain open to speculation.

Theories now advanced to explain golden trout origins are founded, by and large, on a small, but growing, understanding of relationships among present-day populations of *Salmo*. One school suggests that the two subspecies of golden trout in the upper Kern River drainage originated from "two independent invasions by already divergent forms of the golden trout complex." One invasion, supposedly giving rise to *S.a. aguabonita*, originated in the lower Colorado River system; the other, ancestors of *S.a. whitei*, came from the north and are thought to be similar to the "redband" trout of northern California and southern Oregon.

Based on a different interpretation of Pleistocene geography, another school holds that migration of trout from the southeast was unlikely and suggests that both golden trout subspecies stemmed from a single ancestral form that originated in the north and entered the Kern River drainage from the Sacramento and San Joaquin valleys.

It is also possible that the golden trout ancestor was hybrid—originating from a cross between ancient forms of the cutthroat trout (now known as *S. clarki*) and the rainbow trout (now know as *S. gairdneri*). There are close affinities among these three species; many of the genetic and morphological characteristics of golden trout are found in either rainbow or cutthroat trout or in both.

Because of the sketchy fossil record and the difficulty involved in tracing golden trout antecedence, one can only speculate about the true age of goldens as a presumably distinct species. It is known that reproductive isolating mechanisms among most species of *Salmo* are far from complete. This invariably raises the question of whether the golden trout is truly a distinct species. If one accepts the criterion that a species must be isolated reproductively from all other

species, then the golden trout is not a separate species nor, for that matter, is the rainbow trout or the inland cutthroat trout. These three groups of trout can interbreed, and their hybrid offspring are fertile.

Yet golden trout are distinct from other species of *Salmo*. For example, they differ in size, body shape, scale number, coloration, spotting patterns, and chromosome number. On the basis of these important characteristics, taxonomists classify golden trout as a separate and distinct species. Perhaps, given time, goldens would have evolved according to the so-called biological definition of a species—that of reproductive isolation. That is, if it were not for the coming of man.

Certainly it appears that man's actions have been directed, for the most part, toward insuring the future stability of golden trout. Taken at face value, most published data argue against the possible extermination of goldens. As a result of the artificial propagation of fertilized eggs harvested annually from trout in the Cottonwood Lakes, transplanted golden trout are abundant throughout many Sierran waters. Moreover, their numbers appear to be relatively stable in the upper Kern River drainage, despite heavy fishing pressure in easily accessible areas. But underlying the "stability" of golden trout are ominous signs. Two very real and pressing threats to the golden trout confront biologists and fishery managers—species elimination and species contamination.

The threat of species elimination stems from the artificial distribution of animal species with which golden trout cannot compete. Goldens are threatened directly by competition from eastern brook trout in lakes, decimation of their juvenile populations by predacious brown trout, and destruction of their stream habitat by beavers introduced into the South Fork region in 1950.

The apparent abundance of golden trout in streams and lakes outside their native habitat is illusory because their numbers are regularly augmented by hatchery-reared fingerlings. Golden Trout Creek and South Fork of the Kern River goldens, *S. a. aguabonita*, are threatened by beaver damage to their stream habitat and spawning beds. Golden trout require shallow, gravelly areas in which to spawn and cannot tolerate the heavy siltation of their spawning beds that

results from dam construction by beavers. Moreover, beavers alter the complexion of the cool, swiftly flowing shallow streams native to golden trout in this drainage by destroying riparian cover, damaging timber, and clogging the waterways. Predacious brown trout, with their insatiable appetite for other, smaller trout, have noticeably reduced golden trout numbers in the South Fork of the Kern headwaters.

Programs of control and eradication are being undertaken against the beaver and brown trout and studies are under way to determine the effects of overgrazing by livestock and resultant erosion of stream habitats in meadows of the South Fork plateau.

Another cause for great concern is the threat of species contamination arising from hybridization between golden and rainbow trout in the Little Kern River drainage. Restoration and protection of *S. a. whitei* in their native southern Sierra waters is of small long-range value unless goldens of pure stock can be definitively identified. From 1931 to 1941, streams in the Little Kern River basin were planted annually with 85,000 to 100,000 rainbow trout. Although a cessation of rainbow trout stocking was recommended in 1941, when the danger of possible hybridization between goldens and rainbows was recognized, the damage had already been done. Goldens and rainbows did hybridize, and the resultant hybrids were viable and fertile.

Geneticists at the University of California at Davis are working to determine relationships among populations of *S. a. whitei* and to develop parameters whereby pure strains of golden trout may be identified. A portion of the trout analyzed in these studies are sacrificed immediately and preserved for future cytogenetic (chromosomal) and biochemical analysis. The remaining trout are allocated for studies of their morphological and meristic characteristics. The data from these studies are gathered and fed into a computer. Elaborate printouts of results are subjected to complicated statistical analyses. These critical results indicate that it is possible to distinguish pure forms of golden trout. Moreover, it is now known that small, isolated populations of these pure forms are in existence above natural stream barriers that prevented migration and subsequent contamination with hybrids.

The dilemma is complicated—that

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of use versus preservation. Golden trout have existed for perhaps thousands of years, gradually migrating, adapting, and changing in accord with the eccentricities of nature. Man, in less than one hundred years, has disrupted this course of evolution and changed the conditions favorable for their existence.

Another possible evolutionary disruption may be at work if a "founder's effect" obtains for those goldens artificially propagated from stocks in the Cottonwood Lakes. These stocks are derived from the original transplant of a few goldens (*S. a. aguabonita*) from Mulkey to Cottonwood Creek by the Stevens brothers in 1876. Trout from this limited gene pool are distributed annually in streams and lakes throughout the Sierra. Although they are definitely golden trout, it is possible that they have begun to differ genetically from other populations of *S. a. aguabonita* within the South Fork drainage.

As the popularity of the golden trout and of the southern Sierra high country increases, so too does man's impact. In this land of thick forests, delicate meadows, and spectacular mountains, the golden trout thrives—eminently suited to the cascading streams of the upper Kern River drainage. This fragile land must be protected. The success of programs designed to restore and preserve native golden trout populations is dependent on this protection. A Golden Trout Wilderness Area was proposed and studied by U.S. Forest Service personnel, but unfortunately, in 1973, the Little Kern drainage region was deleted from the proposal. Crucial to this administrative decision was pressure from logging interests and Mineral King developers seeking to advance their own opportunities for profit by utilizing portions of the Little Kern basin. This conflict has yet to be resolved.

Little is known about the natural history of golden trout despite the attention paid them by conservationists and scientists in recent years. The implementation of studies on their behavior and ecology, as well as further scientific inquiries into the genetics and evolution of golden and other closely related trout species, is vital to any program designed to restore and protect golden trout and their habitat. Surely golden trout, so beautiful, rare, and still threatened, merit this consideration. □

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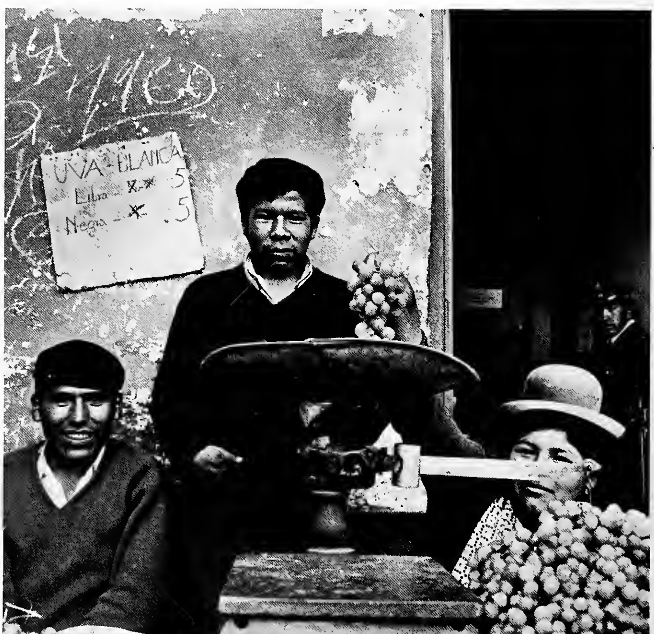

La Paz, Bolivia

Beryl Goldberg

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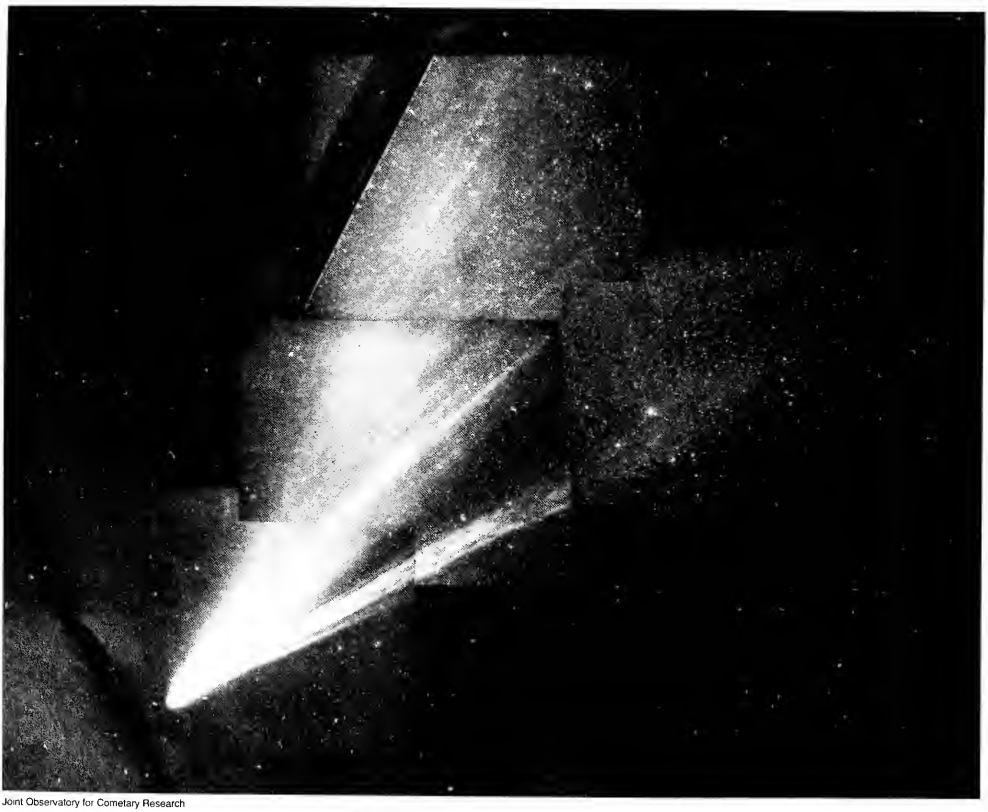
The Splitting of Comet West

This 1976 comet was not only brighter than predicted but also exhibited the phenomenon of a multiple nucleus

In February and March of 1976, a bright comet was the object of intense scrutiny by astronomers at optical, infrared, and radio observatories and was also examined by ultraviolet instruments launched aboard NASA rockets. These studies led to new findings on the composition of the cometary nucleus and to a better explanation for the shape of comet tails. But the most provocative results came when the solid nucleus of the comet split apart in stages, providing researchers with the rare opportunity to observe four separate nuclei in a single comet.

The new comet was first photographed on August 10, 1975, with a one-meter Schmidt telescope at the European Southern Observatory (ESO) in Chile and subsequently on August 13 and September 24 with the same instrument. On each occasion, two photographs were actually taken, but the faint cometary images were not noticed until November 5, when the glass negative, or "plate," of one of the September photographs was examined by Richard M. West, a Danish astronomer at the ESO headquarters facility in Geneva, Switzerland. On this plate, which had been



Joint Observatory for Cometary Research

by Stephen P. Maran

exposed at the telescope for one hour, he found the small, dim comet, more than 200 million miles from earth in the inconspicuous southern constellation Microscopium. Although still far outside the orbit of Mars, the approaching comet, later named for West, had already developed a distinct tail. West was able to locate weaker images of the comet on the August plates.

Computations based on the comet's positions in August and September showed that it would move to the north through the fall and winter, becoming well placed for observation from the Northern Hemisphere after approaching within 19 million miles of the sun at perihelion on February 25, 1976. When this information was reported, astronomers everywhere began planning studies of the new comet. By late December 1975, Comet West, although still a dim telescopic object, was distinctly brighter than predicted by the computations. This trend continued in January, and by early February, sightings had been reported from Australia, New Zealand, South Africa, Japan, Arizona, and elsewhere. The comet had already been spotted through binoculars and was approaching naked-eye visibility. On February 5, perhaps mindful of the earlier public disappointment over Comet Kohoutek (*see* "A Funny Thing Happened to Comet Kohoutek," *Natural History*, March 1974), the director of the Central Bureau for Astronomical Telegrams in Cambridge, Massachusetts, warned astronomers that the excess brightening might not continue into the prime viewing period after perihelion on February 25.

However, in keeping with the capricious nature of many comets, West actually reached a maximum brightness perhaps twenty times greater than that originally predicted. Atop Kitt Peak, west of Tucson, Arizona, I had a fine view of it shortly before sunrise on a late February morning. In the distance, many of the lights of Tucson were still on, and early risers driving along State Highway 86 had not yet extinguished their headlights. But the eastern sky above the Santa Catalina Mountains was already so bright that no stars were visible when Comet West's brilliant coma, or "head," came into view. A short length of the tail could also be seen despite the breaking dawn. A week or so later, the comet was fainter but much better positioned for viewing in the night sky several hours before sunrise. Under these conditions, I saw it easily from a residential street in heavily light-polluted Los Angeles. Also about this time, in early March, mountaintop observers and viewers aboard aircraft reported that West had developed a long, broad dust tail, with prominent curved bands that led some astronomers to report the presence of multiple tails.

The tail structures of Comet West, as shown in a mosaic of Schmidt telescope photographs, stretched more than 30 million miles into space. On March 9, 1976, when these pictures were taken, the comet was 83 million miles from earth and heading back out into the far reaches of the solar system. Exposed to bring out faint details of the tail, this mosaic is necessarily overexposed in the region of the comet's brilliant head and thus the four nuclei present at the time cannot be distinguished here.

Its appearance now reminded one senior comet expert of the Great Comet of January 1910, whose display surpassed that of the more famous Comet Halley in the same year.

Although the coma, which consists of a cloud of escaping gas, may be many tens of thousands of miles in diameter and the tail may stretch for millions of miles into space, the nucleus of a comet such as West is probably no more than a mile or two in diameter. According to the famous "dirty iceberg" theory of comets, the nucleus is composed of frozen gases and water ice, interspersed with microscopic rock particles known as dust grains. There may also be a large rock at the center, but no one knows for sure. Two rocket-borne instruments, launched on March 5, 1976, detected ultraviolet light from carbon monoxide gas in the coma of Comet West, and an analysis by physicists at Johns Hopkins University has since confirmed that frozen CO was a principal constituent of the nucleus.

As a comet approaches the sun from deep space, it is warmed and the frozen water vapor and other iced gases of its outer layer evaporate into space, blowing the dust along with them. The dust grains are then subject to two additional, competing forces: gravity, which pulls them toward the sun, and a counterforce caused by the tiny particles of sunlight called photons, which pushes them away. The latter force is the dominant one, and as a result comet tails usually point away from the sun, so that the tail follows the head when the comet is bound toward the sun, but leads the way when the comet heads back out again through the solar system.

The distribution of frozen gas and dust in the nucleus may not be homogeneous. In that case, as successive layers evaporate, different amounts and kinds of substances are released into space. An example of that process is the slightly curved formations—known as synchronic bands—seen in the dust tail of Comet West. According to existing theory, each band is composed solely of dust particles that were released at the same time (hence, "synchronic"). If the cometary nucleus were homogeneous and released matter into space in a fairly uniform manner, then the dust tail would be composed essentially of an infinite number of adjacent synchronic bands, each corresponding to a particular instant of ejection. In that case, one band would blend into the next one, so that the tail would have an over-all homogeneous look. On the other hand, if the ejection of dust occurred in a small number of separate bursts, then one distinct band, well separated from the next, would be present for each burst. Along the length of a synchronic band, the dust particles closest to the head of the comet are the most massive ones; they are repelled least effectively by sunlight. The far reaches of a band are composed of the smallest particles, which are correspondingly repelled most rapidly.

The problem with this interpretation of comet tail structure is that the orientations of the synchronic bands, as computed from theory, do not always correspond to the form of the bands as actually photographed. This is especially true of some of the prominent bands in the dust tail of Comet West, which showed a pronounced tilt with respect to their calculated orientation. This problem was investigated by Zdenek Sekanina, a specialist in comets at the Center for Astrophysics, Cambridge, Massachusetts, who studied a number of the early March 1976 photographs of Comet West. Sekanina, who has already written several significant papers on this comet, discovered that the observed orientation of each tilted band could be accounted for if the band originated when a single large dust particle that had been blown out of the nucleus later disintegrated to produce a large number of microscopic grains. Thus, it is reasoned that all of the material in a tilted synchronic band did leave the nucleus at a given instant, but the pressure of sunlight did not begin to act on the individual microscopic grains until the larger particle burst apart.

During the same March week investigated by Sekanina, when the synchronic bands were seen in Comet West, telescopic observers discovered a much more exciting phenomenon. On March 5, two nuclei were seen, and the news spread that the comet had split. By March 11, four nuclei had been reported. They were promptly labeled A, B, C, and D. Apparently, Comet West had split, not once, but three times. Although it is not a very common event, nuclear splitting has been observed in previous comets. If a comet gets too close to the sun or to Jupiter, past experience shows that tidal pull exerted by those bodies may rip the nu-

cleus apart. However, some comets, like West, have split when they were too far away from any large celestial object for tidal force to have played a role. Such splittings have been ascribed to a variety of causes—from vapor outbursts, chemical explosions, and heat shock to break-up as a result of the nucleus spinning too fast.

The actual splitting of Comet West was not seen, since the fragments were initially so close together that they could not be separately distinguished by earthbound observers. Nevertheless, by studying the motions of the four fragments, Sekanina was able to extrapolate their trajectories backward in time and to estimate the dates on which the disruptions occurred. It appears that on at least one, and perhaps two, of these dates, the splitting was accompanied by an extensive ejection of dust, which produced enhanced infrared radiation recorded at the University of Minnesota's O'Brien Observatory, and on the third date, radio emission ascribed to the ejection of a cloud of ice grains, each perhaps a few millimeters in diameter, was recorded by two NASA astronomers at the National Radio Astronomy Observatory in West Virginia.

Nucleus A was clearly the main, or original, nucleus, for it followed the predisruption orbit most closely and was usually the brightest of the four objects, whose brightnesses fluctuated. Nucleus C, which apparently separated from A on March 5, was the smallest nucleus, with a diameter that may have been less than 300 or 400 feet. By March 27, according to a report from Arkansas, C had faded to one-hundredth the brightness of A, and by the end of March it had vanished, perhaps as a result of further fragmentation. A, B, and D, on the other hand, were still going strong when last photographed in August 1976.

When a comet splits, its nuclei gradually move apart. The rate at which a new, or "daughter," nucleus moves away from its parent was assumed in the past to be determined by the velocity of the daughter at the moment of separation. But Sekanina recently proposed a new theory that ascribes the motion of separation to the so-called nongravitational force. A planet moves through the solar system primarily under the influence of the gravitational attraction of the sun, with some minor effects exerted by the gravitation of the other planets. Comets, on the other hand, often follow trajectories that cannot be fully accounted for by gravitation. Instead, it appears that the outflow of gases from the comet nucleus acts like a rocket exhaust, propelling the nucleus in the opposite direction in accordance with Newton's law that for every action, there is an equal and opposite reaction. (A comet is thus much like an interplanetary spacecraft such as the *Viking*, which travels most of the way from earth to its target planet on a ballistic trajectory determined by gravity, but which occasionally modifies its path when small jets are fired to make mid-course corrections.)

If gas evaporated equally from all parts of a comet's nucleus at a given moment, the gas would stream equally in all directions and there would be no propulsive effect. However, there is much more evaporation on the side of the nucleus that faces the sun than there is on the opposite side, and this difference generates the nongravitational force. When Sekanina tested his new theory on the extensive set of observations of the four Comet West nuclei that have been reported by astronomers, he found excellent agreement of theory and measurement, confirming that the nongravitational force is the dominant effect that separates the nuclei once a comet has split. Nevertheless, the actual cause of the nuclear disruption remains unknown.

When Comet Kohoutek failed to perform as anticipated in early 1974, a *New York Times* columnist referred to it as "The Comet That Couldn't." By contrast, Comet West in 1976 exceeded its predicted maximum brightness by a comfortable factor, displayed a tail worthy of the Great Comet of January 1910, and capped the display with a threefold nuclear splitting. New findings resulting from studies of the comet amply rewarded the attention lavished on it by astronomers. Yet, like many happy events, the new comet's exhibition went largely unrewarded by editorial attention, even though West, which is due to return in about one million years, has surely earned the sobriquet, "The Comet That Could!"

Stephen P. Maran is studying stars at the University of California in Los Angeles on a temporary assignment from NASA's Goddard Space Flight Center in Greenbelt, Maryland.

by Gerald Oster

The Deceiving Eye

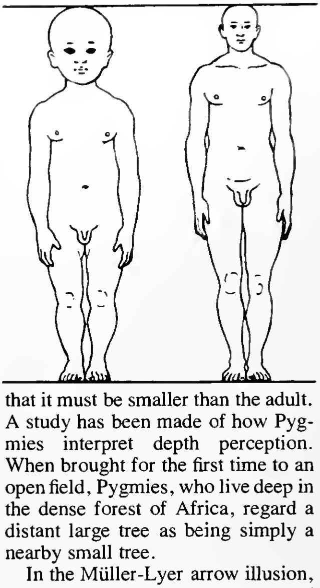
Perspective, distortion, and experience shape the image we think we see

Do we really see what we think we see? Take, for example, a wheel. A wheel is really circular, but it only looks so when viewed straight on. When viewed obliquely, a wheel looks elliptical—and the more obliquely it is viewed, the thinner is the ellipse. What falls on our retina is the image of an ellipse; what occurs to us in our mind is a transformed ellipse, a circle. From previous experience we know that the ellipse we see is a distortion, a transformation, of the circle. We know that a wheel must be circular if it is to be a good, nonbumping wheel.

Nature abounds in transformations that we readily recognize. Thus the relative growth of portions of our body changes continuously as we pass from the fetal stage to adulthood. But the rate of growth is not uniform. Great growth spurts with pronounced transformations take place, for example, during puberty. The biologist Julian S. Huxley appreciated the importance of relative growth (allometry), which he expressed mathematically in terms of geometrical transformations. Allometry has applications to many areas of biology and has been applied to the forms of plants in various ecological situations, as with the shape difference between alpine and valley plants of the same species.

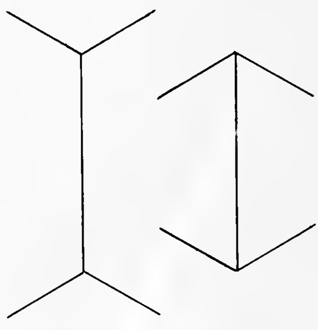
Transformations occur not only in growth but also in the evolutionary process. Thus the skull of the adult baboon can be regarded as an elongated human skull. The late zoologist D'Arcy Thompson used transformations to demonstrate the evolution of one species into another. But later, Julian Huxley was to caution against the applicability of transformation arguments in evolution unless comparisons are made of the animals at the same stage of growth. Thus the skull of the baby baboon resembles the adult human skull, but the skull of the adult baboon differs markedly from that of the adult human. This, indeed, has caused some confusion among anthropologists when on a few occasions the skull of a "missing link" has turned out to be the skull of an ape.

Experience forms an important part of our judgment of distance. We learn that things look smaller when they are at a distance; larger when they are close by. But how can we be sure that the object we are seeing is actually nearby and is really small? Here again, experience helps us make the choice. Thus, shown a drawing in which an adult and a two-year-old child are the same size, we would have the impression that the adult is farther away than the child. We recognize the form of a child and know



that it must be smaller than the adult. A study has been made of how Pygmies interpret depth perception. When brought for the first time to an open field, Pygmies, who live deep in the dense forest of Africa, regard a distant large tree as being simply a nearby small tree.

In the Müller-Lyer arrow illusion, which is also thought to be governed by our experience, the figure on the



Anamorphoses: Games of Perception and Illusion in Art

This exhibit will be at

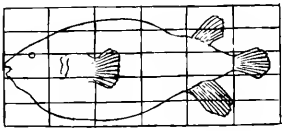
The Brooklyn Museum
Brooklyn, New York
December 17, 1976–
February 13, 1977

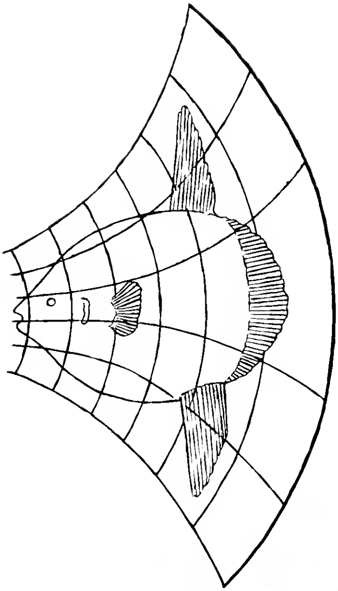
Cleveland Museum of Art
Cleveland, Ohio
March 30, 1977–May 15, 1977

Museum of Science and Industry
Chicago, Illinois
June 15, 1977–September 8, 1977

Corcoran Gallery of Art
Washington, D.C.
October 20, 1977–
January 15, 1978

The High Museum of Art
Atlanta, Georgia
March 1, 1978–May 1, 1978

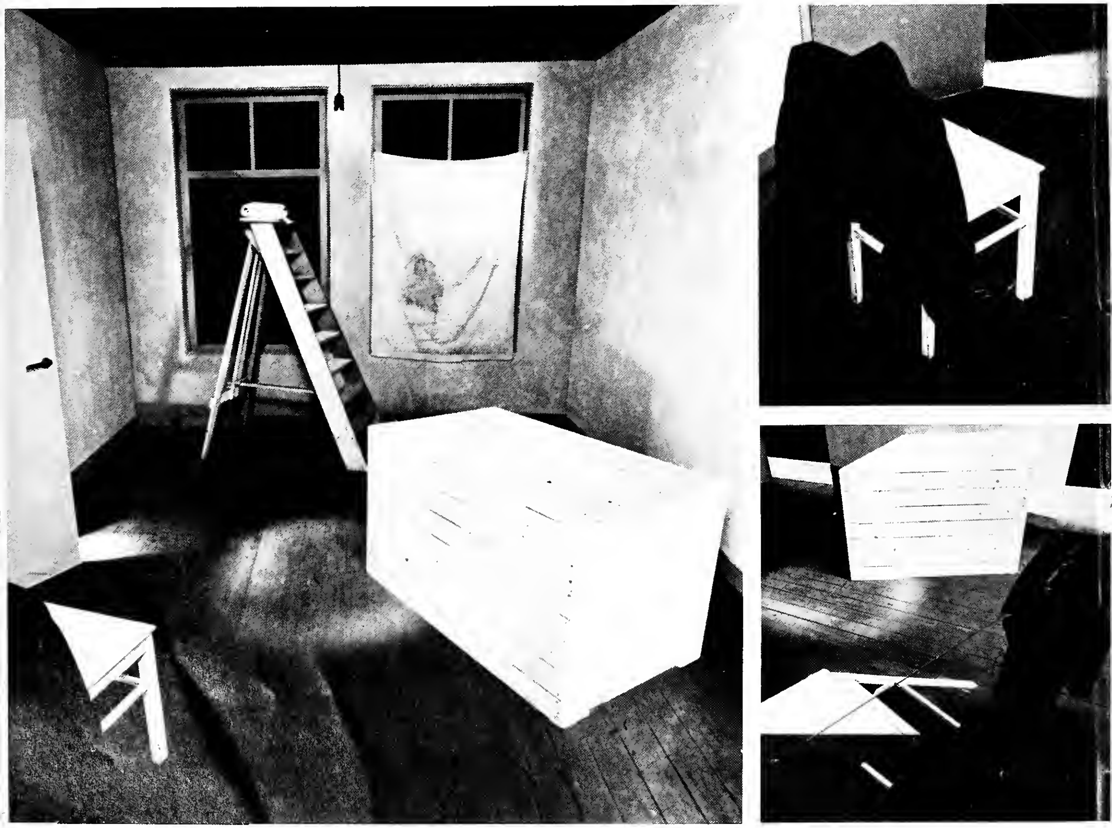




D'Arcy Thompson's demonstration that the teleost Diodon *is related to the sunfish* Mola. *The rectangular coordinates have been transformed to the curvilinear coordinates.*

left is reminiscent of the corner of a room and seems closer to us and hence larger looking. The right-hand figure, which is reminiscent of a corner of a building, suggests that the corner is farther away from us than the corner of the room and therefore appears smaller. If there is validity to this theory, then people without a similar experience in perspective should not sense this illusion. A study of such people, the Zulus (who live in round houses), was actually undertaken. Statistically, the Zulus appeared uncertain as to which vertical line in the illusion appeared longer. (I suspect, however, that the inconclusive response of the Zulus was merely an expression of their incredulity that Europeans would waste their time on such trivia.)

The diminishing size of distant objects is widely used by artists to impart a feeling of depth to the surface of the painting to which they are restricted. This urge to create a three-dimensional illusion on a surface has



The objects in Jan Beutener's The Room *have been carefully constructed so that they appear normal only when viewed through a peephole.*

existed in artists since the Stone Age. Thus in a Paleolithic etching on bone, the feeling of space is created by showing the legs and antlers of reindeer as if seen beyond the fully sketched animals of the foreground. Artists of ancient Egypt expressed depth in a highly stylized manner. They showed two aspects of the human figure. The face was given only in profile, but the shoulders only as a front view. This practice, which was continued by the Egyptians for more than three thousand years, was modified in the 1940s by Pablo Picasso, who showed in some of his paintings a face simultaneously in various angles of observation. The Persians of the Middle Ages seemed to have mixed feelings about representations of depth. When a rug is depicted in their drawings it is seen without perspective so as to present the design of the rug without spoiling its beauty.

Perspective drawing, the most persuasive means of creating the illusion

of depth, reached its culmination with its codification by the fifteenth-century Italian artist Paolo Uccello. In so-called one-point perspective, the artist chooses a vanishing point where all the parallel lines of the real world converge at a point. Thus, the rails of a railroad seem to converge at the horizon. Traditionally, the artist guides himself toward the vanishing point by occasionally holding up his thumb at arm's length and looking beyond it with one eye. In Leonardo da Vinci's *Last Supper*, the vanishing point is at the head of Christ; this has the effect of focusing attention there. In his painting *The Card Players*, Cezanne places a vanishing point at the table as if to enhance the attention of the players.

The Renaissance painters were taxed to their limit when required to transform linear perspective to the curved surface of the domed ceilings of churches. One late-seventeenth-century artist, Andrea Pozzo, managed to transform linear perspective so that his mural inside the hemispherical dome of the church of Saint Ignazio in Rome seems to be painted on a flat surface.

A related transformation is encountered by map makers. Correctly representing the surface of the earth on the flat map is a formidable problem. Most maps are transformations of the curved surface of the earth onto a cylinder, the rolled-up map. Mercator, the sixteenth-century Flemish cartographer achieved this, but not without some compromises. The polar regions are expanded out of proportion while the equatorial countries appear somewhat squashed. Mercator carried out a conformal transformation so as to preserve angles between the coordinates expressing the latitudes and longitudes. With the Mercator projection a navigator pursuing a fixed course on the compass need only make sure that he crosses successive meridians at the same angle.

Perspective, like so many techniques in art, can be carried to the point of extreme. Some examples of Renaissance paintings, especially of long palace courtyards, use perspective to such an extent that it has a disturbingly unreal quality. Indeed, the technique has been used in our century by Chirico and Dali to achieve a dreamlike or surrealistic quality. In the fifteenth century, Leonardo da Vinci, in a break with tradition, distorted some of the fig-

ures in his drawings so that they only appeared realistic when looked at from the edge of the paper. (The technique of distorting a scene so it appears correct when appropriately viewed is encountered in most stage scenery.) Fifth-century B.C. Athenian architects employed the device known as entasis, a slight convex curvature, whereby the columns of a temple were modified so as to look correct to a viewer standing in front of it. In the most notable example of the use of entasis, the Parthenon, these slight transformations imparted a vitality and overcame the inward sagging illusion of the columns.

Distortions in paintings can be used to conceal their contents. In the painting *The Ambassadors*, by Hans Holbein the Younger, there is an unrecognizable diagonal streak that turns out to be a human skull if the painting is viewed from its right-hand edge. Holbein is said to have concealed the skull to serve as a reminder that death is always present. The Chinese concealed figures (usually in erotic situations) in an ingenious way that influenced a number of seventeenth-century European artists. In order to properly see the figures in the painting a cylindrical mirror was required. Examples of this technique are known as anamorphic art (from the Greek *ana*, "again," and *morphe*, "form"). These works of art are distorted in such a manner that they can be viewed properly only from one oblique angle or with the use of a corrective accessory such as a cylinder, cone, or pyramid shaped mirror. To render the painting intelligible, the viewer must see it at the appropriate angle or with the appropriate mirror.

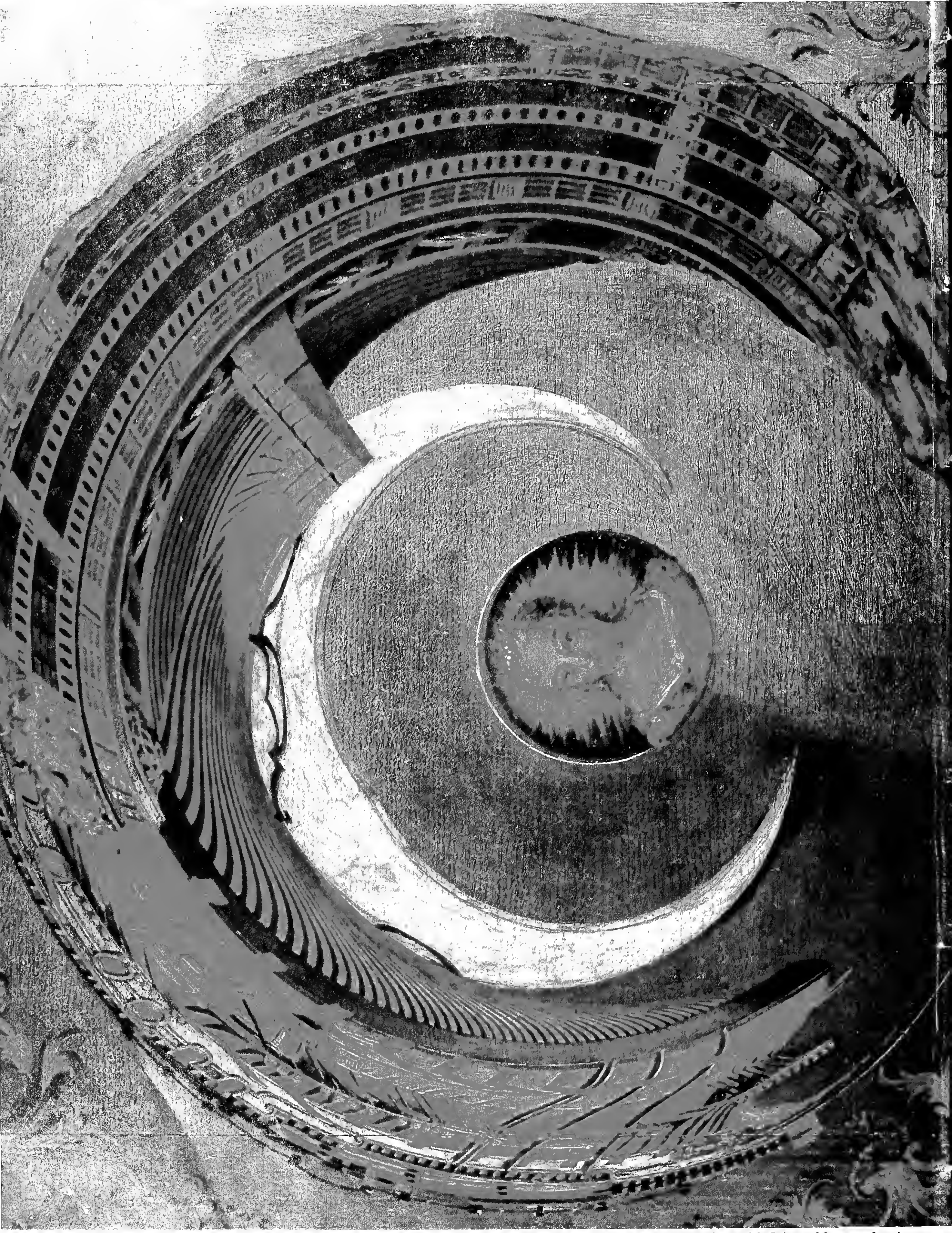
Anamorphosis was revived in this century, notably by Salvador Dali. Recently the technique has enjoyed a vogue, especially in Holland. An exhibit of anamorphic art prepared by Joost Elllers and Michael Schuyt has enjoyed considerable success in Europe and is now being shown in the United States. Among the newer features of the exhibit is an anamorphic room by Jan Beutener. The room contains some hanging cloth and disconnected pieces of wood: viewed through a peephole, however, it becomes a normal, furnished room. When someone walks through the room it appears, through the peephole, that the person is actually walking through solid furniture.

One could make anamorphic art utilizing lenses. One lens would distort the object; when viewed through a compensating lens, however, the object would appear normal. After all, people with astigmatism are always seeing distorted objects until they put on their glasses. It has been conjectured that El Greco painted di-

To view concealed pictures on pages 98–100, roll a sheet of Mylar or other reflecting material into a cylinder and place on indicated circles.

Portrait of a Man Standing Before a Balustrade. Johann König (?) ca. 1630. Universitätsmuseum, Uppsala

Photographs on pages 98–100 from *Hidden Images*, published in 1976 by Harry N. Abrams, Inc., New York



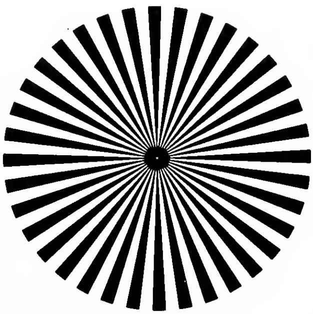
H.M.S. Victory. James Steere (?) After 1786. Science Museum, London

Sleeping Venus Uncovered by Amor. Henry Kettle, ca. 1770. Collection Schuyt, Amsterdam

A Couple. Jean-François Niceron, ca. 1635. Galleria Nazionale d'Arte Antica, Rome

agonally elongated figures because of his uncorrected astigmatism.

An element missing from the anamorphic art exhibit is that of motion. Objects in motion appear different from when they are stationary. Of course, an object will appear blurred if it is moving so rapidly that it is perceived in less than one-twentieth of a second. At slower speeds, however, it will appear compressed in the direction of its motion. This compression due to motion can be regarded as the visual analogue of Einstein's theory of special relativity. In relativistic theory an object cannot move faster than the speed of light (analogous to the blurring of the very fast moving object). At speeds less than the speed of light, the object is transformed into a compressed object. The



Hold figure at arms length and move from side to side. Notice how compression opens angles in the direction of motion. The same compression effect is achieved by holding the page obliquely.

object is more compressed the closer its velocity approaches the speed of light. In perceiving a moving object there seems to be a certain finite time (about one-twentieth of a second) for the nervous system to perceive the object. During that time the object will have already moved. The same transformations postulated in Einstein's theory therefore apply to this simple perceptual problem. My guess is that animals in the wild instinctively use the Einsteinian transformation when making a single strike at a rapidly moving prey.

Gerald Oster is professor of biophysics at the Mount Sinai School of Medicine of the City University of New York.

Additional Reading

Bubble Trade (p. 38)

Don M. Street's *A Cruising Guide to the Lesser Antilles* (New York: W.W. Norton & Company, 1974, $15), a yachtsman's handbook of waters also plied by smugglers, contains a number of anecdotes about illegal trading. "Reavers, Privateers and Smugglers" is a 40-page chapter in Horace Beck's *Folklore and the Sea* (Middletown: Wesleyan University Press, 1973, $14.95), a compendium of superstitions, customs, and beliefs expressed in the folklore of the Caribbean. See also *Folk-Lore of the Antilles, French and English*, edited by Elsie Clews Parsons (New York: American Folklore Society, 1943); Parsons was an anthropologist who collected vernacular accounts of the folklore of New World blacks. Although dealing mainly with Jamaican customs, Robert Dirks's "Slaves' Holiday" (*Natural History*, December 1975, pp. 82–90) provides much of the background from which present beliefs arose throughout the Caribbean. Henry H. Bell, once the governor of Grenada, mentioned smuggling in his book, *Obeah: Witchcraft in the West Indies*, published in London in 1889 and reprinted by Negro Universities Press.

Pelican Colonies (p. 48)

William H. Behle's *The Bird Life of Great Salt Lake* (Salt Lake City: University of Utah Press, 1958, $4.50) and the *Handbook of North American Birds*, edited by Ralph S. Palmer (New Haven: Yale University Press, 1962), both describe the general biology and life history of the white pelican. For more specific information, see George B. Schaller's "Breeding Behavior of the White Pelican at Yellowstone Lake, Wyoming" (*Condor*, 1964, vol. 66, pp. 3–23). David Lack's *Ecological Adaptations for Breeding in Birds* (New York: Halsted Press, 1968, $13.50) contains general material on colony nesting. F. Fraser Darling's classic work, *Bird Flocks and the Breeding Cycle: A Contribution to the Study of Avian Sociality* (Cambridge, England: The University Press, 1938), stimulated much research on the ecological and behavioral adaptations of colonially nesting seabirds. Examples are "Size of Breeding Colony Related to Attraction of Mates in a Tropical Passerine Bird," by N.E. Collias and E.C. Collias (*Ecology*, 1969, vol. 50, pp. 481–88); "Adaptive Significance of Synchronized Breeding in a Colonial Bird," by S. T. Emlen and N. J. Demong (*Science*, 1975, vol. 188, pp. 1029–31); "Colonial Nesting and Social Feeding as Strategies for Exploiting Food Resources in the Great Blue Heron," by J.R. Krebs (*Behaviour*, 1974, vol. 51, pp. 99–134); and "Late-blooming Terns," by Paul A. and Francine G. Buckley (*Natural History*, April 1976, pp. 46–55).

Inca Highways (p. 58)

Peru Before the Incas, by Edward Lanning (Englewood Cliffs: Prentice-Hall, 1967, $2.95), and *The Peoples and Cultures of Ancient Peru*, by Peruvian archeologist Luis G. Lumbreras (trans. by Betty J. Meggers, Washington: Smithsonian Institution Press, 1974, $15), provide background on ancient Peru. In *The Incas of Pedro de Cieza de León* (trans. by Harriet de Onis, Norman: University of Oklahoma Press, 1969, $8.95), Victor W. von Hagen has edited a native Peruvian chronicler's first-hand observations of the period just after the Spanish conquest. See also John H. Rowe's article, "Inca Culture at the Time of the Spanish Conquest," in the *Handbook of South American Indians*, vol. 2, *The Andean Civilizations*, edited by Julian Steward (Washington: Bureau of American Ethnology, 1946, pp. 183–330). A number of articles provide specific information on the economy, administrative control, and road system of the Incas: John V. Murra's

"Cloth and Its Functions in the Inca State" (*American Anthropologist*, 1962, vol. 64, pp. 710–28); Craig Morris's "State Settlements in Tawantinsuyu: A Strategy of Compulsory Urbanism," in *Contemporary Archaeology*, edited by Mark P. Leone (Carbondale: Southern Illinois University Press, 1972, pp. 393–401), and "Reconstructing Patterns of Non-Agricultural Production in the Inca Economy," in *Reconstructing Complex Societies*, edited by Charlotte B. Moore (Cambridge: American Schools of Oriental Research, 1974, pp. 49–68); and Murra and Morris's: "Dynastic Oral Tradition, Administrative Records and Archaeology in the Andes" (*World Archaeology*, 1976, vol. 7, pp. 267–79). Victor W. von Hagen's popular book *Highway of the Sun* (New York: Duell, Sloan and Pearce, 1955) is based on an early survey of the Inca road system.

Marine Archeology (p. 70)

Based on findings of underwater archeological explorations, *Navies of the American Revolution*, by A. Preston et al. (Englewood Cliffs: Prentice-Hall, 1975), is an informative popular account of this period in American history. Preston is an archeologist-historian at the National Maritime Museum in Greenwich, England. George F. Bass, a pioneer in the use of scuba-diving techniques in underwater exploration, has edited, with Richard K. Winslow, *A History of Seafaring Based on Underwater Archaeology* (New York: Walker Publishing, 1972); this volume contains such accounts as Mendel Peterson's "Traders and Privateers Across the Atlantic: 1493–1733" (pp. 253–80). Bass has also written *Archaeology Beneath the Sea* (New York: Walker Publishing, 1975) and *Archaeology Under Water* (Baltimore: Penguin Books, 1972, $1.95). *History Under the Sea: A Manual for Underwater Exploration*, by Mendel Peterson (Washington: Smithsonian Institution Press, 1965), discusses exploration techniques, preservation methods, and dating of underwater artifacts. The *International Journal of Nautical Archaeology and Underwater Exploration* is a quarterly publication devoted to this relatively new science. A book has also been written on the main subject of our article: F. P. Schmitt and D. E. Schmid's *H.M.S. Culloden* (Mystic: Marine Historical Association, 1961).

Golden Trout (p. 74)

Barton W. Evermann's "The Golden Trout of the Southern High Sierras" (*Bulletin of the U.S. Bureau of Fisheries*, 1905, vol. 25, pp. 1–51) is a comprehensive, yet elegant, account of the life cycles and special habitat requirements of the golden trout, and offers a turn-of-the-century recommendation for their protection. Stuart E. White, a contemporary of Evermann, provided historical accounts of the discovery of golden trout in his writings. Two, from 1902 and 1904, which have been reprinted, are *Blazed Trail* (Boston: Gregg Press, $12.50) and *Blazed Trail Stories and Stories of the Wild Life* (New York: Somerset Publishing, $9.50). Charles McDermand's *Waters of the Golden Trout Country* (New York: G.P. Putnam's Sons, 1941) is a fisherman's book, containing descriptions, supplemented with maps and photographs, of the area where these trout are found. Hal Roth's *Pathway in the Sky: The Story of the John Muir Trail* (Berkeley: Howell-North Books, 1965, $8.50) contains excellent photographs of the Sierras—their geology, flora, and fauna—including color pictures of golden trout. For recent accounts of the status of the golden trout, see Peter B. Moyle's "Fish Introductions in California: History and Impact on Native Fishes" (*Biological Conservation*, 1976, vol. 9, pp. 101–18) and his book, *Inland Fishes of California* (Berkeley: University of California Press, 1976), and C. B. Schreck and R. J. Behnke's "Trouts of the Upper Kern River Basin, California, with Reference to Systematics and Evolution of Western North American *Salmo*" (*Journal of the Fisheries Research Board of Canada*, 1971, vol. 28, pp. 987–98).

Anamorphic Art (p. 94)

Richard L. Gregory's *Eye and the Brain* (2nd ed. New York: McGraw-Hill Books, 1973, $2.95) is a stimulating popular account of the psychology of seeing. Gerald Oster's "Optical Art" (*Applied Optics*, November 1965, pp. 1359–69) is a technical account of the biophysics of vision applied to the interpretation of art. An inexpensive abridged edition of D'Arcy Thompson's classic discussion of transformations applied to evolution, *On Growth and Form*, edited by J.T. Bonner, is now available (New York: Cambridge University Press, 1961, $4.95). Another classic, *Problems of Relative Growth*, Julian Huxley's treatment of the topic of allometry, has also been reprinted (2nd ed. New York: Dover Publications, 1972, $3.50). *Hidden Images: Games of Perception, Anamorphic Art, Illusion*, text by Fred Leeman; concept, production, and photographs by Joost Elffers and Mike Schuyt (New York: Harry N. Abrams, Inc., 1976), is a profusely illustrated account of this art form from the Renaissance to the present. Included is a large section on anamorphic puzzles and a reflector to aid the reader in deciphering them. One important section of *Illusion in Nature and Art*, edited by Richard L. Gregory and Ernst H. Gombrich (New York: Charles Scribner's Sons, 1973, $9.95), illustrates how predatory animals employ illusion as a weapon, while their prey use illusory coloration and behavior for protection.

Gordon Beckhorn

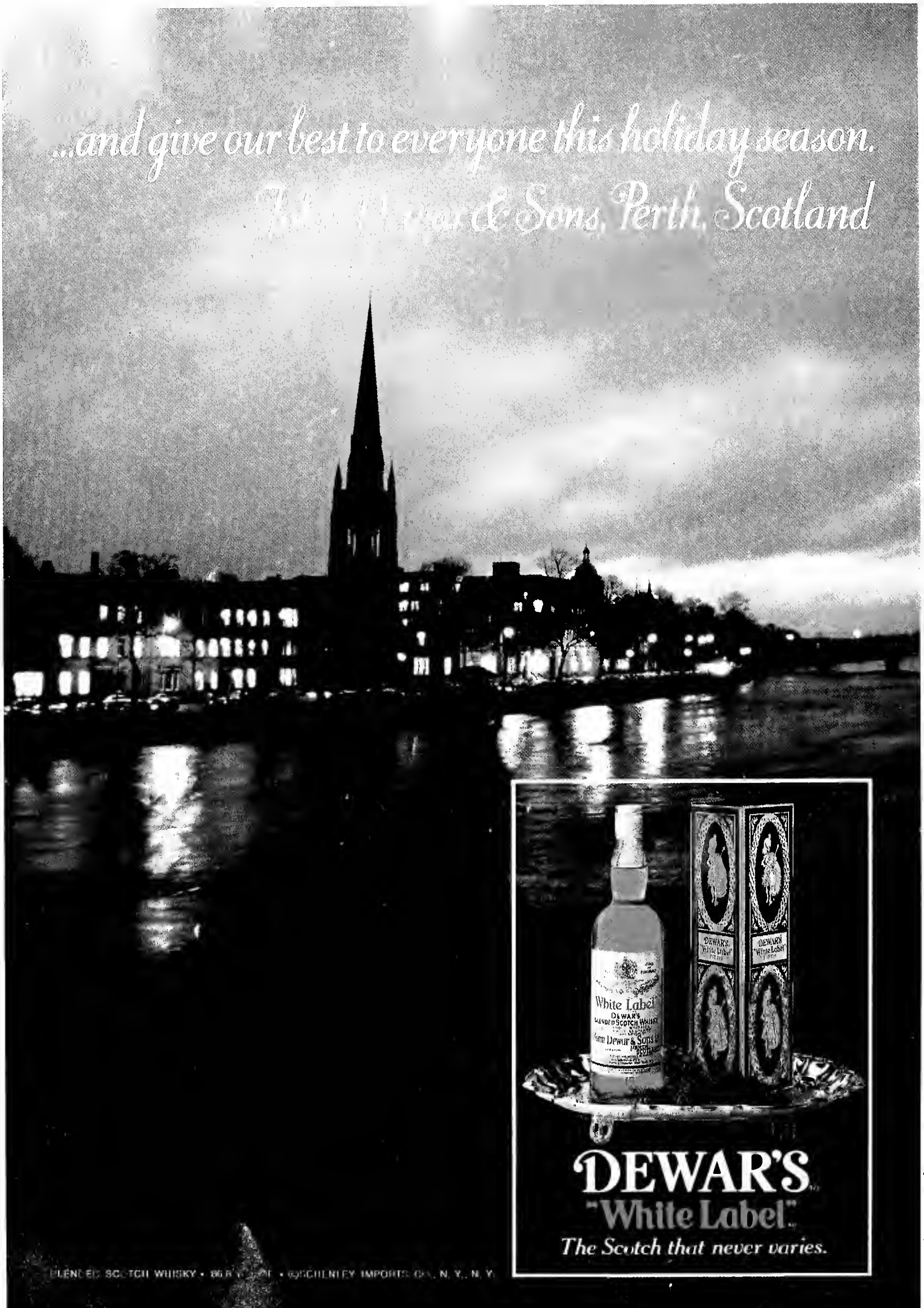
Announcements

The Museum's 25-foot-high artificial **Christmas Tree,** decorated with hundreds of origami figures made by Museum volunteers, will again grace the Roosevelt Rotunda until January 1. In past years, the figures have represented various animals, flowers, fruits, stars, and minerals. New figures this year will include black-and-white animals such as pandas, skunks, and penguins, as well as representations of people, insects, and mollusks.

Places are still available on the Museum-sponsored **Archeological Tour to Mexico,** January 8–29, 1977, which will be led by C. Bruce Hunter, lecturer in archeology at the Museum. The itinerary will include some of the most famous archeological sites in Mexico, such as the pyramids and temples at Malinalco, Tula, Cholula, and Teotihuacán. The tour will also visit the hilltop city of Xochicalco, as well as the ruins at Mitla and Monte Albán, and participants will have an opportunity to visit the Anthropology Museum in Mexico City.

At the **Hayden Planetarium** of the Museum, "Star of Wonder" will open on December 1 and run through January 3, 1977. After looking at the brilliant skies of winter, the planetarium projector will journey back through time to the first Christmas to examine the astronomical possibilities of the star that led the Wise Men of the East to Christ's birthplace nearly 2,000 years ago. Was it a comet? a bright meteor? a nova? Sky Shows begin at 2:00 and 3:30 P.M. on weekdays with more frequent showings on weekends. Admission is $2.35 for adults and $1.35 for children and students (special rates for groups and senior citizens).

Note: Due to renovations, the main auditorium of the Museum will be closed to the public through January 1977.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& Sons, Perth, Scotland
White Label
DEWAR'S
DEWAR'S
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